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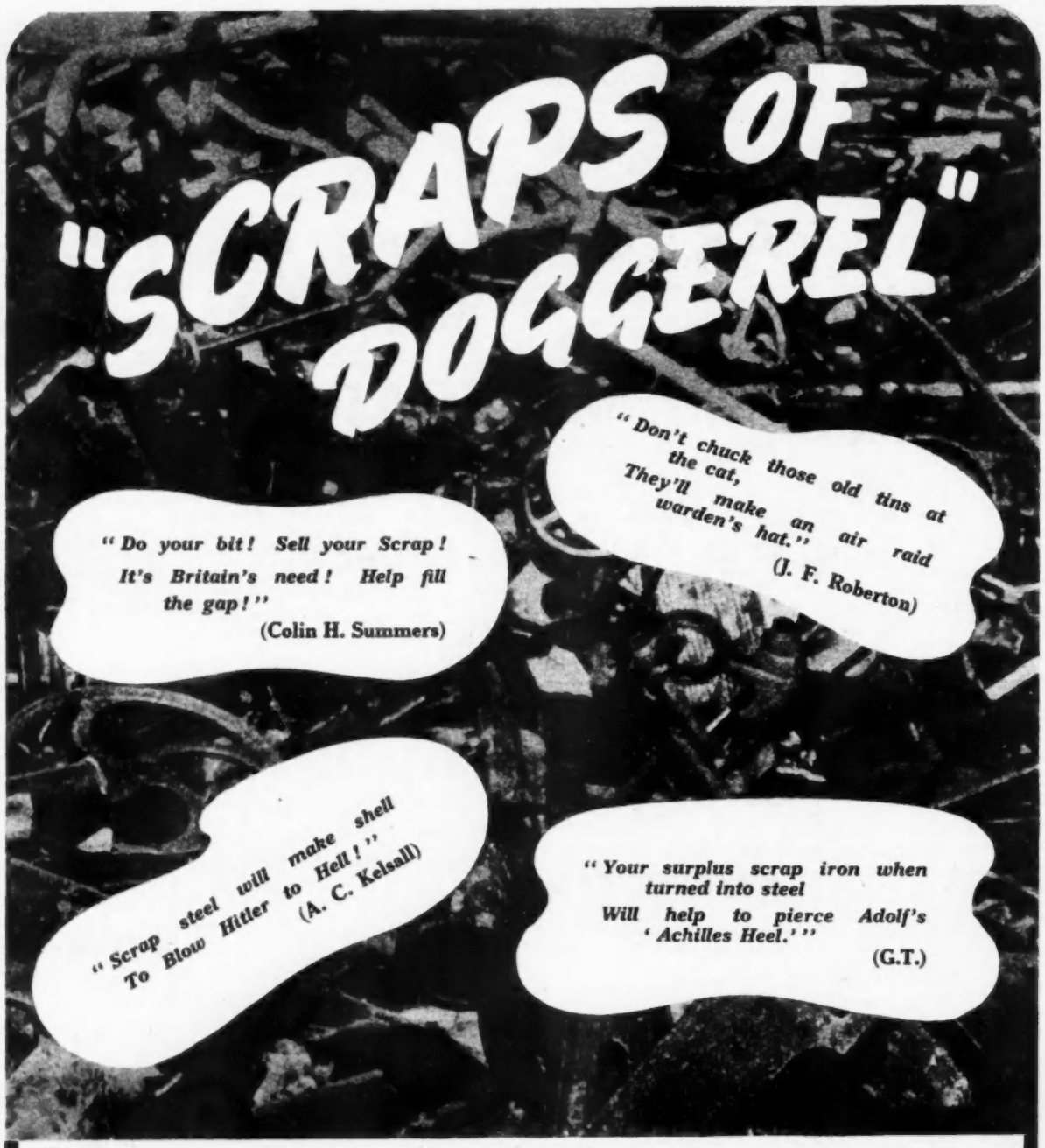
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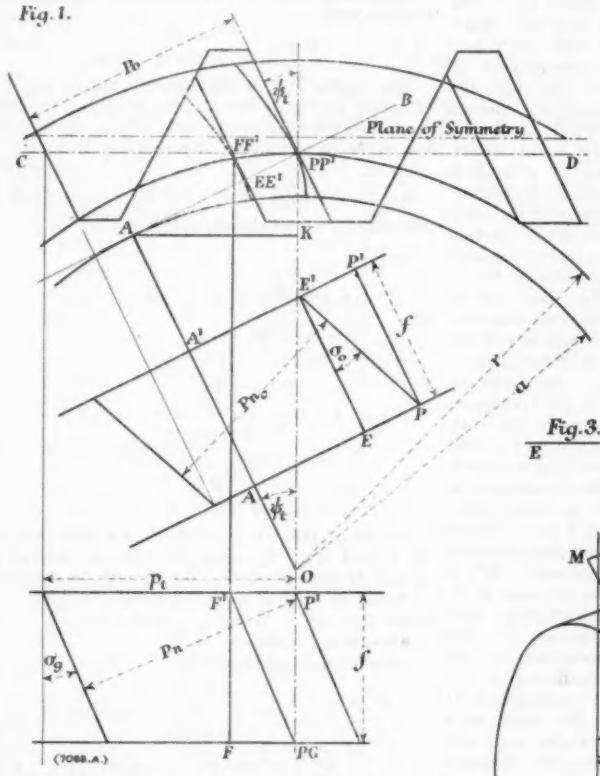
DESIGN OF SPIRAL GEARS.

By W. A. TUPLIN, D.Sc.

IT is well known that the centre distance of a pair of involute spur gears may be varied over a limited range without impairing the smooth meshing of the teeth. The lower limit to centre distance is that which causes the teeth to become tightly meshed or, if there is considerable backlash between the teeth, that which causes the tips of the teeth of one gear to make contact with the roots of those of the other gear. The upper limit is that which causes the path of contact to become so short that one pair of teeth has passed out of it before the succeeding pair has entered it. Beyond this limit, one gear may continue to drive the other, but in a harsh and jerky manner which indicates that, in certain phases of engagement, correct tooth action is not occurring and that the ratio of angular velocity transmission is not uniform. Since a helical gear is equivalent to an infinite number of infinitely narrow spur gears differing from each other only in angular position, a pair of such gears meshed with axes parallel likewise permits of variation in centre distance. Helical gears meshed together with axes not parallel are usually known as spiral gears. It may be shown that such gears will operate correctly with slight departures from the designed centre distance and shaft angle. By taking advantage of this, it is sometimes possible to use a standard cutter to produce gears which would otherwise demand a special one.

Fig. 1.



Generation of Helical Gears.—The contact conditions in spiral gears are conveniently investigated by reference to an imaginary rack. Such gears are usually generated by rack-shaped cutters or their equivalent, and analysis is simplified by starting from a "basic rack" corresponding to a cutter by which the gears might have been produced. Fig. 1 represents a rack set with the length of its teeth inclined at an angle σ_g to the axis of a gear-blank, the axis of which is represented at O in the upper view. The fully-lined rack-form represents the nearer face of the rack lying perpendicular to the axis of the gear. The interrupted rack represents the section on a corresponding plane distant f from the end plane. In the process of generation, the rack moves at a uniform rate from right to left and the blank is rotated uniformly in the counter-clockwise direction at such a rate that it makes a complete revolution while the rack moves through a distance $t\,p_t$, where t is the number of teeth required in the gear and p_t is the "transverse pitch" of the rack measured perpendicularly to the axis of the gear and parallel to the plane of symmetry of the rack. The pitch circle of generation is that of which the circumferential displacement is equal to the linear displacement of the rack. Its radius r is equal to $\frac{tp_t}{2\pi}$, and the straight line C D touches it at P. The line A B is drawn through P, perpendicular to the straight lines in which the left-hand flanks of the teeth of the rack intersect the transverse plane. The angle between A B and C D is the "transverse pressure angle" Ψ_t. While the rack moves through a distance equal to one pitch horizontally, the corresponding displacement along B A is $p_t \cos \Psi_t$, and this is also the displacement of a point on the circumference of the circle, centre O, which touches B A at A, as its radius A O = O P cos Ψ_t. This is the "base circle" representing a transverse section of the "base cylinder" of the gear, and A B represents a tangent plane to the base cylinder

Fig. 2.

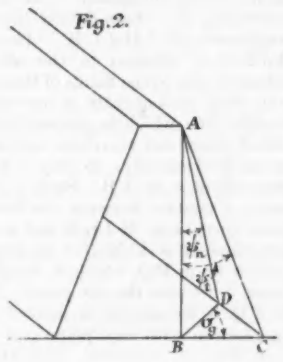
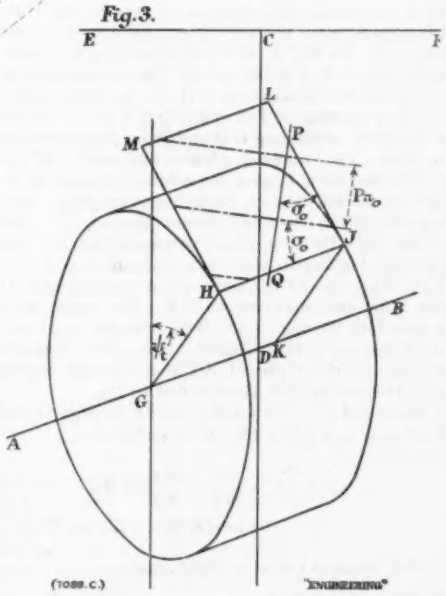


Fig. 3.



Since the flank of the edge of the rack tooth is perpendicular to A B and advances along it in unison with circumferential movement at the base circle, the edge of the tooth always touches, at its intersection with A B, an involute of the base circle. Similar action occurs on other planes, and results in the generation of an "involute helicoidal" tooth, touching the rack tooth along the straight line P E′. In the plane represented in the projected view by A P P′A′, P E′ is inclined to A A′, and to the axis of the gear, at the "base helix angle" σ_o and

$$\tan \sigma_o = \frac{P\,E}{E'\,E} = \frac{P\,F}{f} \cos \Psi_t.$$

The intersection of one flank of a rack tooth with a plane parallel to the plane of symmetry is a line inclined at σ_g (generating helix angle) to the axis of the gear, and

$$\tan \sigma_g = \frac{P\,F}{F\,F'} = \frac{P\,F}{f}.$$

Hence

$$\tan \sigma_g = \tan \sigma_o \sec \Psi_t. \quad . \quad . \quad . \quad (1)$$

In Fig. 2, A B D represents a plane lying perpendicular to the plane of the flank of the rack tooth. The angle D A B is the "normal pressure angle" Ψ_n, and

$$\tan \Psi_n = \frac{D\,B}{A\,B} = \frac{B\,C \cos \sigma_g}{A\,B} = \tan \Psi_t \cos \sigma_g. \quad (2)$$

From (1) and (2) it may be shown that

$$\sin \sigma_o = \sin \sigma_g \cos \Psi_n. \quad . \quad . \quad . \quad (3)$$

Pitches.—The distance between corresponding flanks of adjacent rack teeth measured parallel to the plane of symmetry and perpendicular to the axis of the gear is the "transverse pitch" p_t. The perpendicular distance between corresponding flanks of adjacent rack teeth of the rack measured in a plane perpendicular to the axis of the gear is the "base pitch" p_o. The distance measured parallel to the plane of symmetry and perpendicular to the intersections of the rack tooth flanks with that plane is the "normal pitch" p_n. The shortest distance between the flanks of adjacent rack teeth (measured perpendicular to them), is the "normal base pitch" p_{no}. It is the distance between the traces of adjacent teeth on the tangent plane A P P′A′.

From Fig. 1.

$$p_n = p_t \cos \sigma_g. \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

$$p_o = p_t \cos \Psi_t \quad . \quad . \quad . \quad . \quad . \quad (4A)$$

$$p_{no} = p_t \cos \Psi_t \cos \sigma_o. \quad . \quad . \quad . \quad (5)$$

Substituting in (5) the value of cos σ_o obtained from (1) and (3) by division.

$$p_{no} = p_t \cos \sigma_g \cos \Psi_n. \quad . \quad . \quad . \quad (6)$$

Simultaneous Meshing of Rack with Two Gears.—If the rack be imagined replaced by a series of connected laminæ coinciding with the original exposed surfaces, the resulting imaginary rack may be considered to be meshing simultaneously with a helical gear below it and another above it. Since F′ E′ is perpendicular to the tangent plane A B, the triangle F′ E′ P is right-angled at E′, and

$$\tan \widehat{F'\,P\,E'} = \frac{F'\,E'}{E'\,P} = \frac{F\,E}{E'\,P} = \frac{P\,F \sin \Psi_t}{P\,P' \sec \sigma_o}$$

$$= \frac{F\,F' \tan \sigma_g}{f \sec \sigma_o} \sin \Psi_t.$$

Substituting for sec σ_o and sin Ψ_t in terms of σ_g and Ψ_n by means of (1) and (2), this becomes

$$\tan \gamma = \tan \sigma_g \sin \Psi_n \quad . \quad . \quad . \quad (7)$$

where γ is the inclination of the line of contact E′ P to the direction of the horizontal line F′ P in the rack tooth.

Line of Action.—Now if the upper side of the rack be meshed with another gear, the axis of which is parallel to the plane of symmetry, but not parallel to that of the first gear, the line of contact will be in the flank of the rack tooth but will not, in general, be parallel to E′ P. When the rack is removed, contact between the teeth of the two gears is confined to the point of intersection of their lines of contact with the imaginary rack. Since the point of contact between the teeth must lie on both tangent planes, it is situated in their line of intersection. Since the point of contact moves as the gears revolve, it must follow the straight line in which the two tangent planes intersect. This is the "line of action." It is clear that contact between the gears cannot occur at any point which lies outside the tip cylinder of either of them. Consequently, the length of the path of contact cannot exceed that part of the line of action which lies within the tip cylinders of both gears.

Limitation by Interference.—This may be limited to less than this because no contact can occur beyond the "interference line" which is that in which the tangent plane touches the base-cylinder. (In the upper part of Fig. 1 the interference line lies perpendicular to the plane of the paper and is represented by the point A.)

On this account, the tooth profile produced by any part of a rack-shaped cutter which projects below the line A K is not involute and can have no useful contact with mating teeth. Furthermore, any such part of the cutter actually removes part of the involute profile generated by the remainder of the

cutter. To avoid such interference, the "tip" of the teeth of the cutter (ignoring the allowance for clearance) must not approach the axis of the gear within a distance $O\,K = a \cos \Psi_t$

$$= \frac{t\,p_o}{2\,\pi} \cos \Psi_t$$

$$= \frac{t\,p_n \quad \sec \sigma_g}{2\,\pi\,\sqrt{1 + \tan^2 \Psi_n \sec^2 \sigma_g}} \quad . \quad . \quad . \quad (8)$$

This is derived from (4A), (4) and (2).

This means that while there is latitude in blank diameter for a gear to be produced by a specified cutter, and to have a specified lead and number of teeth, the radius must not be less than the value given by (8) plus the working depth of the tooth.

Limitation by Crest Width.—There is also an upper limit to blank diameter, arising from the consideration that the profiles of each tooth run to an edge if the blank diameter is large. An edge is inadmissible in practice, and it is desirable that the width of the tooth at its crest should not be less than, say, one-twentieth of the normal pitch of the cutter. This width is measured perpendicular to the tooth helices at the crest, and its value is given by:

Crest width =

$$r_c \cos \sigma_c \left[\frac{1}{t}(\pi + 4k \tan \Psi_t) - 2\,(\text{inv}\,\phi - \text{inv}\,\Psi_t)\right] \quad (8A)$$

where

$$k = \left(\frac{\pi\,r_c}{p_n} - 1\right) \cos \sigma_g - \frac{t}{2}$$

r_c = radius of gear at crest,

$$\tan \sigma_c = \frac{2\,\pi}{t\,p_n}\,r_c \sin \sigma_g \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8B)$$

$$\sec \phi = \frac{2\,\pi}{t\,p_n}\,r_c \sqrt{(\cos^2 \sigma_g + \tan^2 \Psi_n)} \quad . \quad . \quad (8C)$$

$$\tan \Psi_t = \tan \Psi_n \sec \sigma_g$$

$$\text{inv}\,\Psi_t = \tan \Psi_t - \Psi_t.$$

Determination of Characteristics of Imaginary Rack.—The fundamental dimensions of gear No. 1 are:

(*a*) The base radius a_1, (*b*) the base helix angle σ_{o1}, (*c*) the number of teeth t_1.

For gear No. 2, the corresponding symbols are a_2, σ_{o2}, t_2.

If the gears are to mesh correctly at all, they must have a common normal base pitch. If the gears are produced by identical cutters this requirement is automatically fulfilled. If the helix angle of generation for gear No. 1 is σ_{g1}, and the normal pressure angle of the cutter is Ψ_n, then from (3),

$$\sin \sigma_{o1} = \sin \sigma_{g1} \cos \Psi_n$$

and

$$\sin \sigma_{o2} = \sin \sigma_{g2} \cos \Psi_n. \quad . \quad . \quad . \quad (9)$$

If the normal base pitch of the cutter is p_{no},

$$a_1 = \frac{t_1}{2\,\pi} \sec \sigma_{o1}\,p_{no},$$

and

$$a_2 = \frac{t_2}{2\,\pi} \sec \sigma_{o2}\,p_{no}. \quad . \quad . \quad . \quad (9A)$$

If, now, the imaginary rack with which the gears work when in mesh at shaft angle Σ has a normal pressure angle Ψ and makes an angle σ_{e1} with the axis of gear No. 1, it makes an angle $\Sigma - \sigma_{e1}$ with the axis of gear No. 2.

Hence

$$\sin \sigma_{o1} = \sin \sigma_{e1} \cos \Psi \quad . \quad . \quad . \quad (10)$$

and

$$\sin \sigma_{o2} = \sin (\Sigma - \sigma_{e1}) \cos \Psi.$$

Comparing these with (9)

$$\frac{\sin (\Sigma - \sigma_{e1})}{\sin \sigma_{e1}} = \frac{\sin \sigma_{g2}}{\sin \sigma_{g1}} \quad . \quad . \quad . \quad (11)$$

Writing

$$\sin (\Sigma - \sigma_{e1}) = \sin \Sigma \cos \sigma_{e1} - \cos \Sigma \sin \sigma_{e1},$$

it is found that

$$\cot \sigma_{e1} = \cot \Sigma + \frac{\sin \sigma_{g2}}{\sin \sigma_{g1}} \text{cosec}\,\Sigma. \quad . \quad (12)$$

This enables σ_{e1} to be determined, and (10) then gives the value of Ψ, after inserting the value of σ_{o1} from (9).

Normally, the generation of the gears is carried out with helix angles the sum of which is equal to the shaft angle at which the gears are to work together. In that case, $\sigma_{g2} = \Sigma - \sigma_{g1}$. Inspection of (11) shows that $\sigma_{e1} = \sigma_{g1}$ and (9) and (10) show that $\Psi = \Psi_n$, *i.e.*, that the imaginary rack during engagement has the same helix angle and pressure angle as the generating rack. It is to be noted that if $\sigma_{o1} = -\sigma_{o2}$ and $\Sigma = 0$, neither σ_{e1} nor Ψ can be determined from a consideration of angles alone. The working helix angle and pressure angle of parallel-shaft gears depend on the relation of centre distance to sum of base radii.

Position of Line of Action.—In Fig. 3, page 187, the cylinder shown is the base cylinder of a helical gear. C D is the common perpendicular to the axis A B of the gear, and E F that of the mating gear. The figure G H J K represents a rectangle containing the axis of the gear and inclined at the transverse pressure angle Ψ_t to the common perpendicular. The figure H J L M is a rectangle containing the line H J, in which G H J K intersects the base cylinder, and lying perpendicular to G H J K. The rectangle H J L M is therefore tangential to the base cylinder. The tooth profiles (not shown) intersect the tangent plane of which H J L M is a part in parallel straight lines (shown chain-dotted) inclined to H J at the base helix angle σ_o, and equally spaced at the normal base pitch p_{no}. The flanks of the imaginary common rack are planes containing the chain-dotted lines and lying perpendicular to H J L M. The counterpart of H J L M in relation to the other gear also lies perpendicular to the flanks of the imaginary common rack, and consequently it intersects H J L M in a straight line which is perpendicular to the chain-dotted lines and therefore inclined at σ_o to H M or, more generally, to any "transverse plane" perpendicular to A B. Such a line is P Q. Any point of contact between the teeth of the mating gears must lie in H J L M and also in the counterpart plane H′ J′ L′ M′ (not shown) in Fig. 3. Hence it must lie in P Q, which is, therefore, the "line of action" between the two gears. Since the direction of P Q is known, it is located completely if its intersection with any plane can be determined.

In Fig. 4, opposite, H J D G corresponds to H J K G in Fig. 3, but J D lies in the transverse plane containing the common perpendicular C D. The tangent plane is represented by H J L M in both diagrams. In Fig. 4, H J L M intersects the plane containing A B and C D in $l\,m$. The counterpart in relation to the mating gear is H′ J′ l' m' intersecting the plane containing E F and C D in l' m'. C S T D is the plane containing C D and lying perpendicular to A B. The tangent planes intersect C S T D in L J, and in $n'\,l'$, and these lines intersect in P. The line of intersection of the tangent planes (the line of action) therefore passes through P. The points $m\,l\,r$ lie in a plane perpendicular to C D. The line $l\,m$ lies in the plane containing A B and C D. The line $r\,l$ is in the plane containing C D and lying perpendicular to C F. The angle $m\,l\,r$ is therefore 90 deg. $- \Sigma$. The triangles $m\,r\,l$ and $m\,n\,l$ are each right-angled at m. The triangle $m\,r\,n$ is parallel to plane C S T D and is right-angled at r, and the angle $n\,m\,r$ is equal to Ψ_{t1}.

Here, and in the following, suffix 1 refers to the lower gear and suffix 2 to the upper gear.

Now,

$$\tan m\,\widehat{l}\,n = \frac{m\,n}{m\,l} = \frac{m\,r}{m\,l} \sec \Psi_t$$

$$= \tan (90 \text{ deg.} - \Sigma) \sec \Psi_{t1}.$$

Also, since J l m is a right angle, $\alpha = \text{J}\,\widehat{l}\,n = 90 \text{ deg.} - m\,\widehat{l}\,n$, and

$$\cot \alpha = \tan m\,\widehat{l}\,n = \cot \Sigma \sec \Psi_{t1}. \quad . \quad . \quad (13)$$

Similar considerations in respect of the triangles $l'\,m'\,r'$, $m'\,r'\,n'$ and $r'\,n'\,l'$ show that

$$\tan \beta = \frac{r'\,l'}{r'\,n'} = \frac{r'\,m'}{r'\,n'} \sec \Sigma$$

$$= \cot \Psi_{t2} \sec \Sigma. \quad . \quad . \quad . \quad . \quad (14)$$

Now

$$D\,l = D\,J \sec \Psi_{t1} = a_1 \sec \Psi_{t1}$$

and

$$C\,l' = C\,J' \sec \Psi_{t2} = a_2 \sec \Psi_{t2}.$$

Hence

$$l\,l' = C\,D - D\,l - C\,l'$$

$$= C - a_1 \sec \Psi_{t1} - a_2 \sec \Psi_{t2} \quad . \quad (14A)$$

where C represents the centre distance of the gears.

But

$$l\,l' = U\,l - U\,l' = P\,U \cot P\,l\,U - P\,U \cot P\,l'\,U$$

$$= P\,U\,(\tan \Psi_{t1} - \cot \beta)$$

$$= P\,U\,(\tan \Psi_{t1} - \tan \Psi_{t2} \cos \Sigma) \quad . \quad \text{(from 14)}$$

Hence

$$P\,U = \frac{l\,l'}{\tan \Psi_{t1} - \tan \Psi_{t2} \cos \Sigma} \quad . \quad (15)$$

Instead of (2) we may write

$$\tan \Psi = \tan \Psi_{t1} \cos \sigma_{e1} \quad . \quad . \quad (16)$$

where Ψ is the normal pressure angle of the imaginary rack, and σ_{e1} is the helix angle of engagement of gear No. 1, determined from (12).

Similarly, $\tan \Psi = \tan \Psi_{t2} \cos \sigma_{e2}$.

Substituting in (15) we have,

$$P\,U = \frac{l\,l'}{\tan \Psi\,(\sec \sigma_{e1} - \sec \sigma_{e2} \cos \Sigma)}$$

$$= \frac{l\,l' \cos \sigma_{e1} \cos \sigma_{e2}}{\tan \Psi\,(\cos \sigma_{e2} - \cos \sigma_{e1} \cos \Sigma)}.$$

Now $\sigma_{e1} + \sigma_{e2} = \Sigma$, and therefore

$$P\,U = \frac{l\,l' \cos \sigma_{e1} \cos (\Sigma - \sigma_{e1})}{\tan \Psi\,[\cos (\Sigma - \sigma_{e1}) - \cos \sigma_{e1} \cos \Sigma]}.$$

Expanding cos $(\Sigma - \sigma_{e1})$ in the denominator, this becomes:

$$P\,U = \frac{l\,l' \cos (\Sigma - \sigma_{e1})}{\sin \Sigma \tan \Psi \tan \sigma_{e1}} \quad . \quad . \quad (17)$$

The length P P′ is that intercepted on the line of action by transverse planes containing the common perpendicular to the axes of the gears. This length is important in determining the path of contact.

In the triangle P P′ l, $\widehat{P'\,P\,l} = \sigma_{o1}$, $\widehat{P\,l\,P'} = 180$ deg. $- \alpha$, and therefore $\widehat{P\,P'\,l} = \alpha - \sigma_{o1}$.

Now

$$\frac{P\,P'}{\sin (180 \text{ deg.} - \alpha)} = \frac{P\,l}{\sin (\alpha - \sigma_{o1})}$$

or

$$P\,P' = \frac{P\,U \sec \Psi_{t1} \sin \alpha}{\sin (\alpha - \sigma_{o1})}$$

$$= \frac{P\,U \sec \Psi_{t1}}{\cos \sigma_{o1} - \sin \sigma_{o1} \cot \alpha}$$

$$= \frac{P\,U \sec \Psi_{t1}}{\cos \sigma_{o1} - \sin \sigma_{o1} \cot \Sigma \sec \Psi_{t1}} \quad \text{(from (13))}$$

$$= \frac{P\,U}{\cos \sigma_{o1} \cos \Psi_{t1} - \sin \sigma_{o1} \cot \Sigma}.$$

By using (16), cos Ψ_{t1} can be expressed in terms of Ψ and σ_{e1}. By using (3) with σ_{e1} instead of σ_g and Ψ instead of Ψ_n, cos σ_{o1} can be expressed in terms of Ψ and σ_{e1}. When this is done, it is found that $\cos \sigma_{o1} \cos \Psi_{t1} = \cos \sigma_{e1} \cos \Psi$.

Also $\sin \sigma_{o1} = \sin \sigma_{e1} \cos \Psi$.

Making these substitutions,

$$P\,P' = \frac{P\,U}{\cos \sigma_{e1} \cos \Psi - \sin \sigma_{e1} \cos \Psi \cot \Sigma}$$

$$= \frac{P\,U \sin \Sigma}{\cos \Psi\,(\cos \sigma_{e1} \sin \Sigma - \sin \sigma_{e1} \cos \Sigma)}.$$

Writing the bracketted expression equal to $\sin (\Sigma - \sigma_{e1})$, and substituting for P U from (17), this becomes

$$P\,P' = \frac{l\,l'}{\sin \Psi \tan \sigma_{e1} \tan (\Sigma - \sigma_{e1})} \quad . \quad . \quad (18)$$

Path of Contact.—Fig. 5 represents an axial view of gear No. 1. The tangent plane is represented by L J, and action within it is limited by the tip circle (at L) or by the root-circle (at V), or by the interference point J (if the root circle is smaller than the base circle). As the line of action P Q (Fig. 4) is inclined at angle σ_{o1} to L J, a true view of the line of action is obtained by projection as at $L_1\,J_1$ (Fig. 5).

The position of P on L J is determined from $P\,l = P\,U \sec \Psi_{t1}$. From the corresponding point p in $L_1\,J_1$, a length pp' is marked off equal to P P′, as calculated from (18).

A similar procedure is followed in connection with gear No. 2, the length corresponding to P l being, by adaptation of (17),

$$\frac{l\,l' \cos \sigma_{e1} \sec \Psi_{t2}}{\sin \Sigma \tan \Psi \tan (\Sigma - \sigma_{e1})} \quad . \quad . \quad (19)$$

The line $L_2\,J_2$ corresponding to $L_1\,J_1$ is then superimposed on $L_1\,J_1$ with the two lengths $p\,p'$ coinciding, as, for example, in Fig. 6. With that disposition of the various points, contact cannot extend to the right beyond V_1 or to the left beyond V_2. The length of the path of contact is, therefore

$V_1 V_2$. It is to be noted that if ll' is positive, *i.e.*, if C is greater than $a_1 \sec \Psi_{t1} + a_2 \sec \Psi_{t2}$, the point P is nearer to the tip circle of gear No. 1 and further from that of gear No. 2 than is P′. If C is less than $a_1 \sec \Psi_{t1} + a_2 \sec \Psi_{t2}$, the opposite is the case. When $C = a_1 \sec \Psi_{t1} + a_2 \sec \Psi_{t2}$, the line of action intersects the common perpendicular and P coincides with P′.

Continuity of Tooth Action.—For continuity of tooth action it is necessary that before one pair of teeth lose contact, a second pair shall have made contact. Since the planes of contact between successive pairs of teeth are parallel flanks of the teeth of the imaginary common rack and the line of action is perpendicular to them, the minimum length of the path of contact for continuous action is equal to the perpendicular distance between such flanks, and this is the normal base pitch p_{no}. In practice, it is found desirable to make the length not less than about $1 \cdot 1\ p_{no}$.

Design Problems.—The conventional method of

Fig. 4.

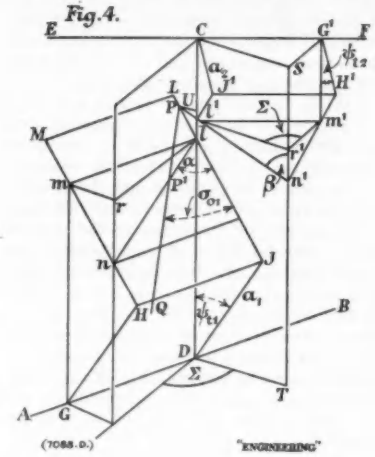
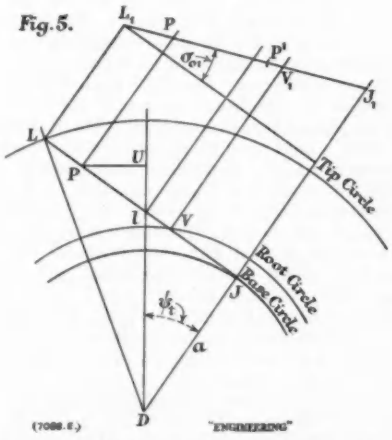


Fig. 5.



designing spiral gears for a specified centre distance and ratio is to assume the use of a cutter of standard normal pitch, and to determine helix angles which will cause the sum of the generating pitch radii to be equal to the centre distance.

If

Σ = shaft angle,
σ_1 = helix angle of gear No. 1,
p_n = normal pitch of cutter,
t_1 and t_2 are numbers of teeth, and
C = centre distance,

this leads to

$$t_1 \sec \sigma_1 + t_2 \sec (\Sigma - \sigma_1) = 2\pi \frac{C}{p_n} \quad . \quad (20)$$

In general, σ_1 must be determined from the equation by repeated trial. It is to be noted that the left-hand side of (20) has a minimum value, and if this is less than the value of $\frac{2\pi C}{p_n}$ corresponding to the originally selected standard pitch, some smaller pitch must be used if it is insisted that the sum of the generating pitch radii shall be equal to the centre distance. Regarded in this light, the expression (20) is a means of determining the greatest normal pitch which it is possible to employ with given numbers of teeth. When a standard value of p_n has been selected, and the corresponding value of σ_1 determined by means of (20), it may be found that the resulting diameters of the gears are inconvenient. In that event, it may be that no standard pitch will fulfil all the requirements.

Again, it may be specified that the gears shall have certain approximate diameters. Subtracting from each of these twice the addendum corresponding to some standard pitch of about the right order, generation pitch diameters d_1 and d_2 are obtained.

Thus

$$\frac{t_1 p_n \sec \sigma_1}{t_2 p_n \sec (\Sigma - \sigma_1)} = \frac{d_1}{d_2}$$

and this leads to

$$\tan \sigma_1 = \left[\left(\frac{t_2 d_1}{t_1 d_2} \right) - \cos \Sigma \right] \operatorname{cosec} \Sigma \quad . \quad (21)$$

which gives σ_1 directly.

Fig. 6.

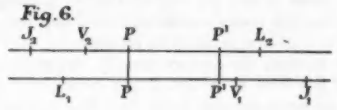
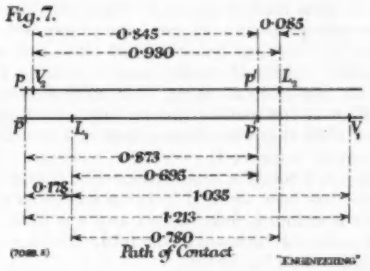


Fig. 7.



Then

$$p_n = \frac{\pi d_1}{t_1} \cos \sigma_1.$$

In general, this value of p_n will not be a standard one. It will be seen that, in some circumstances, it may be impossible to employ a standard normal pitch if the sum of the generation pitch radii is equal to the working centre distance, whereas departure from that restriction might make the use of a non-standard pitch unnecessary. If advantage be taken of this facility, a check calculation must be made to find (*a*) whether the length of path of contact will be reduced by interference; (*b*) whether the teeth of either gear will have inadequate width at the tips; and (*c*) whether the length of the path of contact is sufficient to ensure continuity of tooth action.

Thus, let it be required to design a pair of spiral gears subject to the restrictions: centre distance, 5 in.; shaft angle, 75 deg.; numbers of teeth, 15 and 27. The diameter of neither gear is to exceed 7 in.

Case 1.—Equation (20) is first used to determine approximately the maximum value of the normal pitch. The left-hand side becomes

$$15 \sec \sigma_1 + 27 \sec (75 \text{ deg.} - \sigma_1)$$

It is found by trial that $\sigma_1 = 43$ deg., gives this expression its approximate minimum value of 52·3. Inserting this in (20), the greatest possible normal pitch is

$$p_n = \frac{2\pi \times 5}{52 \cdot 3} = 0 \cdot 6$$

and the standard addendum for this would be $0 \cdot 6 \times 0 \cdot 3183 = 0 \cdot 191$.

On this basis, the diameter of the larger gear is found to be

$$\frac{27 \times 0 \cdot 6 \sec 32 \text{ deg.}}{\pi} + 2 \times 0 \cdot 191 = 6 \cdot 462$$

which is within the specified requirement. Use of a cutter of this pitch will permit satisfactory gears to be made on this basis.

Case 2.—If it be desired to use a standard normal pitch of, say, 0·563 in., for which the standard addendum is 0·179, (20) becomes

$$15 \sec \sigma_1 + 27 \sec (75 \text{ deg.} - \sigma_1) = \frac{2\pi \times 5}{0 \cdot 563} = 55 \cdot 8,$$

whence by repeated trial $\sigma_1 = 29$ deg. 24 min., and the diameter of the larger gear is

$$\frac{27 \times 0 \cdot 563 \sec 45 \text{ deg. } 36 \text{ min.}}{\pi} + 2 \times 0 \cdot 179 = 7 \cdot 268$$

which is inadmissible. Hence no suitable gears can be produced, on this simple basis of design, by a cutter of 0·563 in. normal pitch. Other pitches can be considered similarly.

Alternative Method of Design.—As the larger gear would normally exceed the specified maximum diameter of 7 in., and as there is no restriction on the diameter of the smaller gear, the alternative solution that gives the minimum departure from the usual basis of design is that in which the diameter of the larger gear is the limiting maximum. On this basis

Tip radius of gear No. 2 = 3·5 in.
Nominal pitch radius of gear No. 2 = 3·5 − addendum = 3·5 − 0·179 = 3·321
Hence nominal pitch radius of gear No. 1 = centre distance − 3·321 = 1·679.

Now let the helix angles be tentatively selected so that the pitch radii of generation are proportional to these; *i.e.*,

$$\frac{15 \sec \sigma_1}{1 \cdot 679} = \frac{27 \sec (75 \text{ deg.} - \sigma_1)}{3 \cdot 321},$$

whence

$$\frac{\cos (75 \text{ deg.} - \sigma_1)}{\cos \sigma_1} = \frac{27}{3 \cdot 321} \times \frac{1 \cdot 679}{15} = 0 \cdot 91,$$

or

$$\cos 75 \text{ deg.} + \sin 75 \text{ deg.} \tan \sigma_1 = 0 \cdot 91,$$

whence

$$\tan \sigma_1 = 0 \cdot 673 \text{ or } \sigma_1 = 33 \text{ deg. } 56 \text{ min.},$$

and

$$\sigma_2 = 75 \text{ deg.} - 33 \text{ deg. } 56 \text{ min.} = 41 \text{ deg. } 4 \text{ min.}$$

Check for Possibility of Interference.—Root radius of gear No. 1 = 1·679 − 0·179 = 1·5. From (8), minimum radius for freedom from interference

$$= \left(\frac{15 \times 0 \cdot 563}{2\pi} \right) \frac{\sec 33 \text{ deg. } 56 \text{ min.}}{1 + \tan^2 20 \text{ deg.} \sec^2 33 \text{ deg. } 56 \text{ min.}}$$
$$= 1 \cdot 36.$$

The normal pressure angle of the cutter is taken to be 20 deg.

Root radius of gear No. 2 = 3·321 − 0·179 = 3·142.
Minimum radius for freedom from interference

$$= \left(\frac{27 \times 0 \cdot 563}{2\pi} \right) \frac{\sec 41 \text{ deg. } 4 \text{ min.}}{1 + \tan^2 20 \sec^2 41 \text{ deg. } 4 \text{ min.}}$$
$$= 2 \cdot 6.$$

Hence there is no interference in either gear.

Check for Crest-Width. Gear No. 1.—

Tip radius = 1·679 + 0·179 = 1·858.

From (2)

$$\tan \Psi_1 = \tan 20 \text{ deg.} \sec 33 \text{ deg. } 56 \text{ min.} = 0 \cdot 439$$
$$\Psi_1 = 23 \text{ deg. } 42 \text{ min.} \quad \text{inv } \Psi_1 = 0 \cdot 02532$$

From (8C)

$$\sec \phi = \frac{2\pi \times 1 \cdot 858}{15 \times 0 \cdot 563} \sqrt{(\cos^2 33 \text{ deg. } 56 \text{ min.} + \tan^2 20 \text{ deg.})}$$
$$= 1 \cdot 250 \quad \text{inv } \phi = 0 \cdot 1065$$

From (8B)

$$\tan \sigma_c = \frac{2\pi \times 1 \cdot 858}{15 \times 0 \cdot 563} \sin 33 \text{ deg. } 56 \text{ min.}$$
$$= 0 \cdot 768 \qquad \sigma_c = 37 \text{ deg. } 31 \text{ min.}$$

The crest-width is determined by use of (8A).

$$k = \left(\frac{\pi \times 1 \cdot 858}{0 \cdot 563} - 1 \right) \cos 33 \text{ deg. } 56 \text{ min.} - \frac{15}{2}$$
$$= 0 \cdot 275$$

Crest-width =

$$1 \cdot 858 \cos 37 \text{ deg. } 31 \text{ min.} \left[\frac{\pi + 4 \times 0 \cdot 275 \times 0 \cdot 439}{15} - 2 (0 \cdot 1065 - 0 \cdot 02532) \right]$$
$$= 0 \cdot 116 \text{ in.}$$

Gear No. 2.—Adoption of the foregoing procedure in respect of gear No. 2, the tip radius of which is 3·5 in. leads to the result that the crest-width is 0·149 in. The crest-width of each gear is thus seen to be adequate.

Check for Continuity of Tooth Action.—From

(14A) the value of $l\,l'$ is given in terms of a_1, a_2, Ψ_{t1} and Ψ_{t2}, which are determinable in general from equations (9) to (12). When the shaft angle is the sum of the generating helix angles (as is usual), the procedure is simplified because $a_1 \sec \Psi_t = \frac{p_n}{2\pi} t_1 \sec \sigma_g$, and similarly for gear No. 2.

Here

$$a_1 \sec \Psi_{t1} = \frac{0{\cdot}563}{2\pi} \times 15 \sec 33 \text{ deg. } 56 \text{ min.} = 1{\cdot}62$$

whence

$$a_1 = 1{\cdot}48$$

$$a_2 \sec \Psi_{t2} = \frac{0{\cdot}562}{2\pi} \times 27 \sec 41 \text{ deg. } 4 \text{ min.} = 3{\cdot}203$$

whence

$$a_2 = 2{\cdot}88.$$

Hence

$$l\,l' = 5 - (1{\cdot}620 + 3{\cdot}203) = 0{\cdot}177$$

From (18)

$$\text{P P}' = \frac{0{\cdot}177}{\sin 20 \text{ deg. } \tan 33 \text{ deg. } 56 \text{ min. } \tan 41 \text{ deg. } 4 \text{ min.}} = 0{\cdot}873$$

From (17) the values corresponding to P U for the two gears are

Gear No. 1

$$\text{P U} = \frac{0{\cdot}177 \cos 41 \text{ deg. } 4 \text{ min.}}{\sin 75 \text{ deg. } \tan 20 \text{ deg. } \tan 33 \text{ deg. } 56 \text{ min.}} = 0{\cdot}565$$

Gear No. 2.

$$\text{P U} = \frac{0{\cdot}177 \cos 33 \text{ deg. } 56 \text{ min.}}{\sin 75 \text{ deg. } \tan 20 \text{ deg. } \tan 41 \text{ deg. } 4 \text{ min.}} = 0{\cdot}479$$

Referring to Fig. 5, the actual lengths in this instance are :

Gear No. 1.

$$\text{P}\,l = \text{P U} \sec 23 \text{ deg. } 42 \text{ min.} = 0{\cdot}617$$

$$\text{L}\,l = \text{L J} - l\,\text{J} = \sqrt{(r_c^2 - a_1^2)} - a_1 \tan \Psi_{t1} = \sqrt{(1{\cdot}858^2 - 1{\cdot}48^2)} - 1{\cdot}48 \tan 23 \text{ deg. } 42 \text{ min.} = 0{\cdot}465$$

$$l\,\text{V} = l\,\text{J} - \sqrt{\text{D V}^2 - a_1^2)} = 1{\cdot}48 \tan 23 \text{ deg. } 42 \text{ min.} - \sqrt{(1{\cdot}5^2 - 1{\cdot}48^2)} = 0{\cdot}415$$

Projecting these lengths on to the line of action, which is inclined at σ_{o1} to the transverse plane, they are multiplied by sec σ_{o1}.

From (9)

$$\sin \sigma_{o1} = \sin 33 \text{ deg. } 56 \text{ min. } \cos 20 \text{ deg.} = 0{\cdot}525,$$

whence

$$\sec \sigma_{o1} = 1{\cdot}175$$

$$p\,\text{V}_1 = \text{P V} \sec \sigma_{o1} = (\text{P}\,l + l\,\text{V}) \times 1{\cdot}175 = 1{\cdot}213$$

$$\text{L}_1\,\text{V}_1 = (\text{L}\,l + l\,\text{V}) \times 1{\cdot}175 = 1{\cdot}035$$

$$p\,p' = \text{P P}' = 0{\cdot}873$$

Gear No. 2.

Similar considerations show that $p'\,\text{V}_2 = 0{\cdot}845$; $\text{L}_2\,\text{V}_2 = 0{\cdot}93$; $p\,p' = 0{\cdot}873$.

Fig. 7 represents these numerical values applied to the construction of Fig. 6. It is seen that the path of contact is limited to $\text{L}_1\,\text{L}_2$, the length of which is 0·78 in. The normal base pitch is 0·563 cos 20 deg. = 0·528. As the path of contact is longer than 1·1 times the normal base pitch, continuity of tooth action is assured.

Alterations in Shaft Position for Existing Gears.—The foregoing methods are easily applied to investigate the possibility of change in centre-distance, with or without change in shaft-angle, of existing gears. The procedure is (*a*) determine σ_{e1} by (12) and σ_{e2} by subtraction from Σ ; (*b*) determine Ψ by (10), sin σ_{o1} being already known from (9) ; (*c*) determine Ψ_{t1} and Ψ_{t2} by (2), writing σ_e instead of σ_g and Ψ instead of Ψ_n ; (*d*) determine a_1 and a_2 by (9A) ; (*e*) determine $l\,l'$ by (14A) ; (*f*) determine length of path of contact as already indicated. As change of centre distance or shaft-angle cannot alter the dimensions of existing gears, the questions of interference and crest-width do not require consideration.

ALUMINIUM-BRONZE GRAVITY DIE CASTING.

By DR. ARTHUR STREET.

(*Concluded from page* 161.)

The Effect of Added Elements.—It has been known for some time that the addition of about 3 per cent. of iron to aluminium bronze refines the grain and prevents self-annealing. The addition of each 1 per cent. of iron increases the tensile strength by 2 tons to 2·5 tons per square inch, and this rate of improvement continues with iron additions up to about 4 per cent. The British Standard Specification DTD. 174, for aluminium-bronze die-castings, calls for aluminium 8 per cent. to 10·5 per cent., and iron 1·5 per cent. to 3·5 per cent. Workers in the aluminium-bronze die-casting foundry, however, sometimes report that very high iron contents increase the difficulty of manufacture. This becomes specially noticeable in complicated work, particularly where long cores have to be withdrawn from the die-casting. At the best of times, the pulling of long cores in the gravity casting of aluminium-bronze requires considerable skill and strength, and the addition of iron is likely to increase the difficulty. Because of this, die-casters usually compromise by limiting the iron to about 2 per cent., and if the casting presents special difficulties the iron content may be still further reduced. Table V, opposite, shows the properties of cast aluminium bronzes, containing varying quantities of iron and other elements. Although manganese is not so much used as iron (for one thing, it is more expensive), its effect is the same. Similar remarks apply to nickel, while it is also claimed that nickel additions still further improve the corrosion resistance of the alloys. As a result of recent researches, considerable interest has been aroused in the possibilities of the copper-aluminium-nickel alloys, and it is likely that much more will be heard in the future of aluminium-bronzes containing nickel.

Gravity Die-Casting.—It is well known that die-casting production is classed into two groups depending upon whether the "pressure" or "gravity" process is used. At present, gravity die-casting is the process almost exclusively applied where aluminium-bronze is concerned. Pressure die-casting, involving, as it does, the injection of the alloy into the mould under high pressure and velocity, is not readily applicable to aluminium-bronze because it represents quite the opposite of the non-turbulent condition which is necessary if aluminium-bronze is to be satisfactorily cast. The gravity die-casting of aluminium-bronze appears to have been developed during the war of 1914-1918, and one of the first occasions on which it was publicly referred to at length was at the 1918 May meeting of the Institute of Metals, when Rix and Whitaker,* gave a practical paper on the subject, followed by a discussion of considerable length, indicating the interest which was aroused. Just as the last war made many engineers aware that there was a high-duty alloy called "aluminium-bronze" which might have possibilities, so it may be that in the present war, aluminium-bronze will find many applications. The procedure of gravity die-casting is somewhat similar to that followed in the ordinary foundry except that the moulds and cores are permanent and usually of a ferrous material. In most cases, the whole operation is manual. Usually, the die is reasonably inexpensive—an average figure being about 15*l*. This means that aluminium-bronze gravity casting can often be applied to work in which the quantities required are 1,000, 500, or even less. On the other hand, such die-castings are also used for large scale production running into very many thousands. For instance, the gearbox selector forks of most motor-cars are aluminium-bronze gravity die-castings.

The mould is generally constructed of ordinary or high-grade cast iron, 3 per cent. nickel-steel, or a special alloy cast iron, while the cores and important portions of the die are often made from a heat-resisting alloy steel. If the component is required in small quantities only, it is quite safe to make the die of cast iron, but at present large quantity production is the general rule, so that a die possessing a long life must be constructed. Very often, the die blocks are made of alloy cast iron, but at specially-important points, blocks of alloy steel are let into the die. Fig. 8, opposite, shows the die and cores used to produce an aluminium-bronze shackle for a sports car (the component is shown at the bottom right-hand corner). This photograph is reproduced by courtesy of Messrs. Fry's Diecastings Limited. It will be seen that some of the cores are telescopic ; this is in order to secure a clean edge at the main cored holes. Further, the telescopic cores provide a useful method of venting. The two halves of the die are mounted on a bench and fitted together, using dowels, such as will be seen in Fig. 8. Cores, after having been dipped in a dressing, such as a solution containing graphite in suspension, are inserted into position. The die is clamped together and the metal is poured. After a few seconds, when the casting has become solid, the cores are levered out of position. Referring to Fig. 8, it will be seen that each core is provided with a collar which enables the die operator to extract the core with a pair of levers when the casting has solidified. The die is then unclamped and the casting removed, with the runner and possibly, also, a riser, attached to it. While the die-casting is still red hot it is difficult to see whether surface marks are present, so the part is merely examined to see if it has run properly and is allowed to cool before being inspected. After the casting has been removed the mould is dressed for a further cast. The dressing serves to allow easy extraction of the die-casting, to protect the surface and, incidentally, also to help to cool the mould. The time taken to produce a die-casting naturally depends on the size and complexity of the work. In the case of a small component, the production may average from 30 castings to 40 castings per hour, while with a bulky component it may be less than 10. If the quantities required are very large, it is advisable to provide several sets of dies in order to cope with the requirements.

The best working temperature of the die is between 250 deg. and 400 deg. C. Increased die temperature improves the surface appearance of the product, but too high a temperature leads to reduced life and may also cause porosity. Sometimes it is a temptation to superheat the metal ; for instance, if a plate-shaped part of large area had to be die-cast, the metal would have to be overheated to induce it to run and fill the whole die. Such parts, of thin section but large area, can be produced by gravity die-casting in aluminium-bronze, but the danger of porosity near the runner position is always present. If the mould is used with care, it should last for from 8 to 15,000 castings, but cores, particularly those which become greatly heated, are likely to require renewal at shorter intervals. For instance, in one difficult aluminium bronze die-casting, weighing about 3 lb., a cored hole 6 in. long and 1 in. diameter was included, and, in spite of the fact that the core pin was made of heat-resisting steel, it had to be renewed after every batch of 500 castings. Wear on cores is indicated by hair cracks in the steel and by necking at the end of the core pin. Thus, a cored hole which is coming out under size and has signs of a flash across the end, is an indication that the die-caster should renew the core. When the die-castings are cool they are inspected for dimensional accuracy and surface appearance and are then removed to the trimming section where the runner is cut off. Possibly, also, some machining operations are carried out ; for example, it is often found cheaper to drill a small hole than to form it during the die-casting operation, with the likelihood of frequent core renewals. Thus, holes of less than $\frac{1}{4}$ in. diameter are not usually cast on account of the wear which would occur in the slender core pins. Holes which are cast are tapered by at least 0·015 in. per inch of length ; this is, of course, to facilitate the withdrawal of the core from the rapidly-contracting casting. For a similar reason, faces which occur parallel with the axis of the die are given "leave" so that the casting may be withdrawn from the mould without scoring its surface. It will be appreciated that every die-casting must be examined on its merits and the minimum size of cored holes depends

* See *Jl. Inst. Met.*, vol. 19, page 123 (1918), and ENGINEERING, vol. 105, page 326 (1918).

ALUMINIUM-BRONZE GRAVITY DIE CASTINGS.

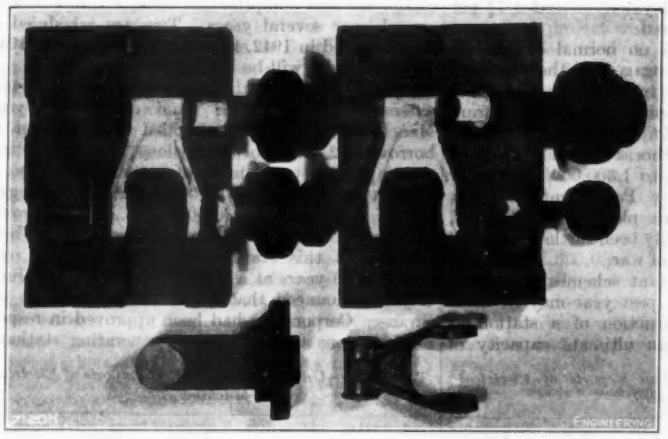


FIG. 8. DIE AND CORES FOR SHACKLE CASTING.

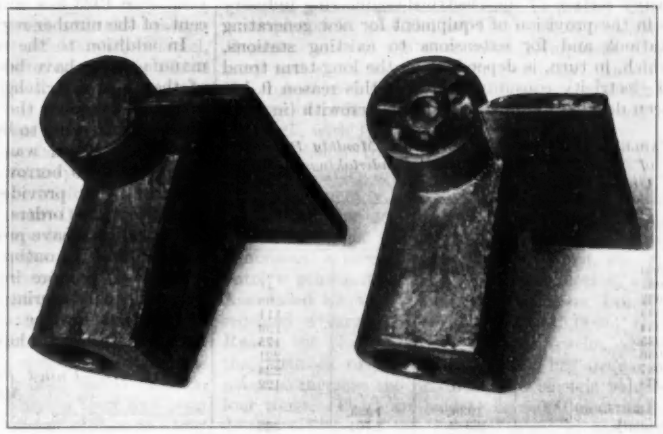


FIG. 9. ORIGINAL AND IMPROVED DESIGNS OF CASTING.

on conditions. Thus a $\frac{3}{16}$-in. hole could be cored if it were only a short one and not too near the runner. On the other hand, a hole 6 in. long and $\frac{3}{8}$ in. in diameter would be a most awkward proposition, both on account of the wear and the bending of the core which would take place when it became hot through contact with the die-cast metal. On account of the high temperature involved, the casting of threads is practically never attempted. Complexities such as crossing cored holes and undercuts should be avoided as their inclusion would slow up production and reduce the life of the dies. In such cases, a subsequent machining operation is usually cheaper, or, better still, the part may be re-designed so that the complexity is eliminated.

Solidity of Aluminium-Bronze Die-Castings.—One of the chief factors affecting the solidity of an aluminium-bronze die-casting concerns the designer of the part. Soundness is more likely to be obtained if the part is uniform in section and of such a design that no locality will solidify before the rest. If the component consists of a heavy mass of metal joined abruptly to a thin wall, solidification would be uneven and, almost certainly, a large contraction cavity would occur in the thick section. By careful attention to design it is nearly always possible to avoid heavy masses of metal and to make the section uniform. A useful working section is $\frac{1}{8}$ in. When a part which was formerly sand-cast is made by die-casting in aluminium-bronze, the section can often be reduced with advantage. The reduction of weight naturally lowers the cost and it should be remembered that the properties of aluminium bronze are such that reduction of section can be undertaken without deterioration in the strength of the article as a whole. Fig. 9 illustrates how uniform section improves solidity. The door-check body in its original design had a section nearly half an inch in thickness at the end of the cylindrical portion, which will be seen at the upper left-hand corner of the casting on the left. A hole had to be drilled into this base, but it was invariably found that irregularly-shaped contraction cavities were present which, firstly, caused the drill to run off at an angle and, secondly, caused the bodies to leak oil and so become unusable. It was realised that this section was unnecessary, although the overall dimensions had to be retained. The die-caster, therefore, made an additional core in order to relieve the base in the way shown in the right-hand casting. In addition, the small hole in the centre was cored to a depth of $\frac{3}{4}$ in., so that all the user had to do was to tap it. In this way, not only was the amount of machining reduced but the danger of the presence of cavities was removed. Sufficient is known concerning the melting of aluminium-bronze for there to be no excuse for porosity caused by overheating or by the presence of gas in the metal. Experience is continually being gained in the methods of producing both foundry castings and gravity die-castings so as to obtain the maximum solidity. As a general rule, the runner must be arranged in such a position that the metal will enter the lower part of the die with as little turbulence as possible and will flow upwards until the die is full. Conflicting streams of metal give rise to discontinuities in the die-casting and should be avoided. Provided that due care is exercised, aluminium-bronze die-castings, with a ruling section of up to $\frac{3}{8}$ in., should be free from porosity.

In conclusion, it may be re-emphasised that the use of the gravity die-casting process enables most or all the machining operations to be eliminated, and it allows rapid deliveries of components to be made at a competitive cost. Moreover, the beneficial effects of the die-casting process on the structure and physical properties of aluminium-bronze are matters which should be of interest to designers and engineers.

TABLE V.—MECHANICAL PROPERTIES OF CAST ALUMINIUM BRONZES.

Composition.					Condition.	Properties.							
Cu.	Al.	Fe.	Mn.	Ni.		Limit of Proportionality. Tons per sq. in.	Yield Point. Tons per sq. in.	Proof Stress (0·15 per cent.). Tons per sq. in.	Tensile Strength. Tons per sq. in.	Elongation on 2 in.	Reduction of Area. Per cent.	Izod Impact. Ft.-lb.	Brinell Hardness. No.
90	10	—	—	—	Sand Cast	5·0	11·2	—	32·2	22	22	22	95
90	10	—	—	—	Sand Cast and Heat-treated	12·1	21·5	—	40·0	8	10	—	175
89	10	—	1	—	Chill Cast	—	16·0	—	39·9	25	—	—	—
89	9	—	2	—	Chill Cast	—	14·2	—	33·2	30	—	—	—
89	10	—	1	—	Sand Cast	—	14·0	—	35·8	22	—	—	—
89	9	—	2	—	Sand Cast	—	10·6	—	31·3	40	—	—	—
89	10	1	—	—	Sand Cast	5·3	12·1	—	33·0	24	24	25	95
86	10	4	—	—	Sand Cast	7·6	14·3	—	36·2	18	18	—	—
88	9	3	—	—	Sand Cast	7·6	13·9	—	34·4	44	36	25	110
88	9	3	—	—	Chill Cast	7·6	15·5	—	38·0	40	36	25	135
85	10	—	—	5	Chill Cast	—	24·8	—	36·2	2	5	—	185
86	9	—	—	5	Sand Cast	—	—	—	33·0	37	37	28	110
84	10	3	3	—	Chill Cast	—	—	14·2	44·1	11	17	—	159
79	9	6	—	6	Chill Cast	—	—	18·2	39·2	15	21	—	—
77	10	3	5	5	Chill Cast	—	—	44·0	50·1	1	2	—	247
72	11	5	1	1	Sand Cast	20	31·2	—	44·7	6	—	—	200

LYONS INTERNATIONAL FAIR.—We are informed that the Lyons International Fair, which was first held during the last war in 1916, is to take place this year from April 13 to 21.

WORM-WHEEL HOBS.—The design of worm gears often suffers from restrictions due to the fact that accurate and economical generation of the wheel teeth necessitate the employment of a hob of which the leading dimensions correspond to the meshing worm. A hob is an expensive tool, and designers are therefore apt to be content with rough approximations in order to utilise hobs which happen to be available. Messrs. David Brown and Sons (Hudd.), Limited, Huddersfield, have some 2,500 hobs in stock, most of them relief ground on the flanks, and have just published a book entitled *The "David Brown" Hob Book*, giving full particulars of them. The book should afford guidance to engineers in the proportioning of worm gears to suit existing hobs. The particulars relate, for the most part, to straight profile worm gears, though a certain proportion of the hobs are for use with the firm's patent worm gear. A useful section of the book deals with nomenclature and notation, formulæ for detail design, and so forth.

THE ENGINEERING OUTLOOK.

V.—ELECTRICAL ENGINEERING.—HEAVY PLANT.

PROBABLY the most important market for the heavy section of the electrical-engineering industry is in the provision of equipment for new generating stations and for extensions to existing stations, which, in turn, is dependent on the long-term trend of electricity consumption. For this reason it has been decided to show in Table I, herewith (in place

TABLE I.—*Great Britain: Average Monthly Production of Electricity by Authorised Undertakings. (Million Units.)*

Monthly Average.	Output.		Increase on Previous Year.
1930	910		—
1931	951		41
1932	1,019		68
1933	1,130		111
1934	1,289		159
1935	1,464		175
1936	1,685		221
1937	1,909		224
1938	2,031		122
	1938.	1939.	
January	2,382	2,704	322
February	2,145	2,334	189
March	2,111	2,508	397
April	1,849	2,046	197
May	1,854	2,068	214
June	1,612	1,912	300
July	1,656	1,918	262
August	1,679		
September	1,872		
October	2,195		
November	2,346		
December	2,675		

of the BEAMA Index of Activity in Electrical Engineering, which is no longer published), the monthly average production of electricity by selected stations in recent years. It will be seen that for each month in 1939 up to July, the latest month for which the figures are available, there was a very satisfactory rate of increase in the number of units generated. For the seven months, January to July, the average increase over the corresponding months of the previous year amounted to 269 million units, compared with average increases of 122 million units for the year 1938 and 224 million units for 1937. It may be noted that, in 1938-39, electricity generated in selected stations comprised 93·6 per cent. of the total generated in the country.

This state of affairs is reflected in the amount of new generating plant sanctioned for selected stations by the Electricity Commissioners, which totalled 919,285 kW in 1938-39, compared with 956,250 kW in 1937-38 and 645,000 kW in 1936-37. Actually, the volume of work sanctioned in 1938-39 was higher in relation to the previous year than is

TABLE II.—*Electrical Engineering: Number Employed.*

Date	Number of Workpeople.			Index. 1923 = 100.
	Insured.	Unemployed.	Employed.	
July, 1923 ..	60,960	3,153	57,807	100·0
„ 1928 ..	79,770	4,000	75,770	131·1
„ 1929 ..	84,430	3,248	81,182	140·2
„ 1930 ..	89,860	7,084	82,776	143·2
„ 1931 ..	92,470	13,185	79,285	137·2
„ 1932 ..	94,080	15,163	78,917	136·5
„ 1933 ..	90,590	13,008	77,582	134·2
„ 1934 ..	91,190	6,720	84,470	146·1
„ 1935 ..	93,410	5,740	87,670	149·9
„ 1936 ..	101,700	3,784	97,916	169·3
„ 1937 ..	114,630	3,018	111,612	193·1
„ 1938 ..	117,710	5,857	111,853	193·4
„ 1939 ..	122,890	3,556	119,334	206·4

indicated by these figures for capacity extensions, as the value of loans by public authorities sanctioned by the Electricity Commissioners totalled 25·3 million pounds in the year ended March 31, 1938-39, compared with 19·7 million pounds in 1937-38. The amount of new generating plant sanctioned in any one year probably gives a fairly good idea of the state of activity in the heavy section of the electrical-engineering industry in the following year, and, therefore, these figures indicate a high level of activity in 1939. This is also confirmed by the employment statistics shown in Table II, on this page. The number of insured workpeople rose from 117,710 in July, 1938, to 122,890 in July, 1939, while at the same time the number unemployed fell from 5,857 to 3,556. The number in employment, therefore, rose from 111,853 to 119,334, more than double the figure for 1923. A remarkable feature of the table is that in no year since 1933 has unemployment exceeded 7½ per cent. of the number registered.

In addition to the work on normal extensions, manufacturers have been engaged on the provision of the pool of switchgear, transformers and other equipment against the possibility of damage from air raids. In order to build up this pool, the Central Electricity Board was authorised under the Civil Defence Act to borrow up to 1,500,000*l.*, a similar amount being provided by Parliamentary grant. The necessary orders were placed in December, 1938, and they have probably been further increased as a result of the outbreak of war.

Among the more important schemes sanctioned or put in hand during the past year may be mentioned that for the construction of a station at Stoke-on-Trent, to have an ultimate capacity of

TABLE III.—*United Kingdom Exports of Electrical Machinery.*

Monthly Average.	Volume.	Index. (1913 = 100.)	Value Per Ton. £.	Index. (1913 = 100.)
1913	2,238	100	85·5	100
1932—				
1st Qr. ..	2,113	94·4	146·0	172·0
2nd „ ..	2,462	110·0	145·0	171·0
3rd „ ..	1,881	84·1	147·0	173·0
4th „ ..	1,622	72·4	156·0	185·0
1933—				
1st Qr. ..	1,481	66·2	153·4	181·5
2nd „ ..	1,413	63·1	155·9	184·5
3rd „ ..	1,389	62·1	147·7	174·8
4th „ ..	1,690	75·5	134·3	158·9
1934—				
1st Qr. ..	1,667	74·5	151·5	179·3
2nd „ ..	1,829	81·7	139·4	165·9
3rd „ ..	1,837	82·1	143·5	169·7
4th „ ..	2,146	96·3	145·0	176·4
1935—				
1st Qr. ..	2,245	100·4	154·0	182·2
2nd „ ..	2,145	96·0	143·5	169·8
3rd „ ..	2,124	95·0	145·6	172·2
4th „ ..	2,544	113·8	155·8	184·3
1936—				
1st Qr. ..	2,727	121·8	154·2	182·5
2nd „ ..	2,325	103·8	158·1	187·1
3rd „ ..	2,556	114·2	155·9	184·5
4th „ ..	2,637	120·1	165·0	196·5
1937—				
1st Qr. ..	2,967	132·6	161·2	190·8
2nd „ ..	2,789	124·6	158·0	187·0
3rd „ ..	2,593	115·9	167·8	198·6
4th „ ..	3,158	141·1	172·2	203·8
1938—				
1st Qr. ..	3,894	174·0	160·1	187·3
2nd „ ..	3,625	162·0	178·2	208·4
3rd „ ..	3,701	165·4	177·4	207·5
4th „ ..	3,665	163·8	192·3	224·9
1939—				
1st Qr. ..	4,296	191·9	171·2	200·1
2nd „ ..	2,605	118·0	189·1	221·0
3rd* „ ..	2,863	128·5	191·6	224·0

* Average of two months.

240,000 kW. The cost was estimated at 2,348,000*l.*, and a four-years' building programme was provided for. It was originally intended to locate the station at Barlaston, a village some four miles from Stoke; in July, however, it was announced that the Electricity Commissioners had refused approval of this site, because of objections by residents on the score of loss of amenities. It was announced that a new site would be sought within the city of Stoke-on-Trent. Another important project is the erection, by the Yorkshire Electric Power Company, of a new station which, it is understood, will cost approximately 1,000,000*l.*

In order to improve the supply position in the Wirral Peninsula, Birkenhead Corporation is to erect a new generating station at a cost of approximately 1,250,000*l.* The initial installation, it has been stated, is to comprise two 30,000-kW turbo-alternators, but the ultimate capacity will be 120,000 kW. In addition to the above, it was announced in June that the Electricity Commissioners had submitted to the Central Electricity Board three schemes involving the erection of nine new generating stations. Of these, five are required for the South-East area, two for South-West England and South Wales, and two for North-East England. In the following month these schemes were adopted without modification, and an additional scheme was put forward for North-West England and North Wales. The latter, which was adopted by the Central Electricity Board at the beginning of October, provides for taking over the Whitebirk generating station of the Blackburn Corporation as a selected station, and the erection of two new stations, each to have an initial capacity of not less than 60,000 kW. The erection of the eleven stations comprised in these schemes will be spread over several years. Two are scheduled to be completed in 1942, two in 1943, and one in 1944. The remainder will be held in reserve.

Apart from new stations, a number of important extensions were put in hand during the year. Manchester Corporation applied for sanction to borrow 892,420*l.* for extensions to their plant. An important programme of extensions is also in hand at Cardiff, where two schemes the aggregate cost of which will exceed 1,000,000*l.*, were approved during the year. Further extensions have been planned at this station, to be carried out over the next 20 years at a cost of 1,500,000*l.* In June, it was announced that a loan of 500,000*l.* to the Swansea Corporation had been approved in respect of extensions to one of their generating stations;

TABLE IV.—*United Kingdom: Net Imports of Electrical Machinery.*

Monthly Average.	Volume.	Index. (1913 = 100.)	Value Per Ton. £	Index. (1913 = 100.)
1913	902	100	115·2	100
1932—				
1st Qr. ..	201	22·0	377·0	327·0
2nd „ ..	144	15·0	495·0	428·0
3rd „ ..	146	16·0	463·0	400·0
4th „ ..	119	13·0	315·0	274·0
1933—				
1st Qr. ..	38	4·2	345·6	300·0
2nd „ ..	65	7·2	297·3	258·1
3rd „ ..	47	5·2	281·2	244·1
4th „ ..	99	11·0	174·7	151·6
1934—*				
1st Qr. ..	152	16·8	203·5	176·8
2nd „ ..	136	15·1	181·1	157·1
3rd „ ..	149	16·6	220·2	191·1
4th „ ..	122	13·4	225·0	194·7
1935—*				
1st Qr. ..	124	13·7	212·8	185·0
2nd „ ..	172	19·1	197·8	171·8
3rd „ ..	136	15·1	221·5	192·3
4th „ ..	121	13·4	224·7	195·1
1936—*				
1st Qr. ..	194	21·6	180·9	157·0
2nd „ ..	243	26·9	186·5	162·0
3rd „ ..	215	24·1	195·5	170·0
4th „ ..	261	29·9	177·5	154·2
1937—*				
1st Qr. ..	227	25·2	213·4	185·2
2nd „ ..	284	31·5	204·2	177·3
3rd „ ..	274	30·4	197·5	171·4
4th „ ..	373	41·4	175·4	152·2
1938—*				
1st Qr. ..	265	29·4	188·5	163·6
2nd „ ..	228	25·3	181·8	157·8
3rd „ ..	186	20·6	196·4	170·5
4th „ ..	150	16·9	257·6	223·6
1939—*				
1st Qr. ..	167	18·5	218·9	190·3
2nd „ ..	190	20·9	210·5	182·9
3rd „ † ..	232	25·7	180·0	156·9

* Gross imports.
† Average of two months.

and one of 281,251*l.* to Halifax Corporation. In August, the granting of a loan to Fulham was sanctioned in respect of power-station extensions. Another important extension to a power station in the North was estimated to cost 436,556*l.*

It is clear, therefore, that the demand for generating plant, which has been running at a high level for some time, is likely to be well maintained over the next few years. There was also an exceptionally heavy export demand, though exports of electrical machinery other than generators were lower in 1939 than in the previous year. Among the larger units completed or in hand, the British Thomson-Houston Company installed the fourth 75,000-kW generator for the County of London Electric Supply Company, a 60,000-kW unit for the Kent Power Company, the fourth 50,000-kW unit for Ironbridge, and a 30,000-kW generator for the Ayrshire Electricity Board. Orders were received for 30,000-kW units for Portsmouth and Leeds, and, in the export field, for a 25,000-kW plant for South Africa and one of 18,750 kW for Brisbane.

The Metropolitan-Vickers Company were engaged in work on a 100,000-kW unit for Battersea and a 60,000-kW set for Brimsdown. The company received a record number of new orders during the year, among which may be mentioned a 60,000-kW plant for the Kent Electric Power Company; two 45,000-kW turbo-alternators, generating at a pressure of 33,000 volts, for Ipswich; and a 32,500-kW set for the Willesden power station of the North

Metropolitan Electric Power Company. The Brush Electrical Engineering Company completed the installation of a 37,500-kW Brush-Ljungström turbo-alternator at Southwick, Brighton, and this was brought into service in June. This company received orders for a 30,000-kW set for Wolverhampton; two 15,000-kW sets for Burton-on-Trent; and four sets of 20,000 kW each for Halifax, York, Lincoln and Sunderland. In the export field, many orders were received, of which the largest was a 20,000-kW set for New South Wales.

The English Electric Company completed two 40,000-kW sets for the Yorkshire Electric Power Company, and a 30,000-kW unit for the South Wales Electric Power Company, from whom an order for a second similar set was received. A number of export orders were received, notably for Australia and South Africa, including one 32,000-kW unit, several 30,000-kW sets, and one 25,000-kW unit. Messrs. C. A. Parsons and Company and the General Electric Company were also prominent in export markets, the former supplying two 50,000-kW turbo-alternators to Australia, a 40,000-kW unit for South Africa, and a number of smaller plants for Australia and Canada; while the latter had under construction a 40,000-kVA set for Johannesburg and a 17,000-kW plant for Adelaide.

There were also a number of interesting units under construction for hydro-electric installations. The Metropolitan-Vickers Company had under construction four large vertical water-turbine alternators rated at 30,000-kVA at 100 r.p.m. The same company also received a repeat order for two 24,000-kVA alternators for the Arapun station of the New Zealand Public Works Department. The English Electric Company had a number of machines under construction for New Zealand, Tasmania, India, and Eire.

In addition to generating equipment, there was a high level of demand for switchgear and transformers. Additional switchgear was required, not only for the new generating stations, but also for new industrial enterprises, particularly the large armament factories. The demand for electric motors for general industrial purposes was also maintained at a high level, though exports showed some falling off. In this country the change-over from group to individual drive continued, creating a considerable demand for the smaller electric motors.

Activity in connection with railway electrification was rather less than in preceding years. In May, the Great Western Railway announced that they had decided not to proceed with the electrification of the main line between Taunton and Penzance, the estimated capital cost of which was over 4,000,000*l.* The scheme would have covered a total route mileage of 232 miles, but an investigation conducted by the consulting engineers showed that the physical characteristics of the line were not particularly suited to electrification. Another reason for abandoning the scheme was the high capital cost of electric locomotives, of which about 164 would have been required.

The Southern Railway extension to Chessington, south of the line from Malden to Tolworth, constructed in the previous year, was completed on May 25. Although this completes the scheme for the time being, it is understood that the line will eventually be continued to Leatherhead and the necessary land has already been acquired by the Railway Company. In the following month a more important project was completed with the opening of the electrified lines to Maidstone, Strood, Rochester, Chatham and Gillingham. This added a further 54 miles to the electrified track of the Southern Railway.

Some important orders were placed during the year in connection with the London and North Eastern Railway's electrification programme. In July it was announced that, in addition to 70 electric trains to be constructed at the Doncaster works of the L.N.E.R., the company had placed orders totalling 1,500,000*l.* with private firms for the building of 100 three-coach electric trains, of which eight were designed to operate on the Manchester-Glossop suburban route and the remainder on the Sheffield and London section. In August, good progress was announced in connection with these electrification schemes, and it was stated that on the Liverpool street-Shenfield line, a start had been made with the erection of overhead girders to carry the transmission wires, while on the Manchester-Sheffield line, overhead girders had been erected for a distance of seven miles at Woodhead, Hadfield and Sheffield. The latter, when completed, will be the first scheme in the country in which all passenger and freight services will be operated with electric multiple-unit trains or trains hauled by electric locomotives. The company also has in hand a number of electrification schemes in conjunction with the London Passenger Transport Board. Work was proceeding on the construction of the tunnels to bring the Northern City line to the surface at Finsbury Park, while at Stratford tunnelling work for the Central Line was nearly complete.

Other tube extensions included the opening, during July, of the extension of the Northern Line from Archway, Highgate, to East Finchley, and the extension of the Bakerloo Line to Stanmore. The importance of these developments for the electrical engineering industry is shown by some of the orders placed.

In May last, the British Thomson-Houston Company received from the L.P.T.B. an order for four air-cooled steel-tank rectifier equipments of 2,000-kW capacity and associated switchgear, and another for twelve 1,500-kW water-cooled rectifiers and switchgear. The same company also received an order for 45 sets of motor-control equipment for non-driving motor cars, and had under construction an experimental Diesel-electric locomotive for the L.P.T.B. The Metropolitan-Vickers Company had in hand the equipment for 70 electric locomotives for the L.N.E.R., as well as export work for the Continent and South America.

Satisfactory orders were also received for trolley 'buses. In May, the Cardiff City Council, after discussions lasting two years, decided to substitute trolley 'buses for trams. In London, trolley 'buses were introduced on an additional 8¾ miles of road in June. This marked the completion of the ninth stage of the North London conversion scheme and increased the route miles of trolley-'bus services to 235, leaving 134 route miles of tramways in the L.P.T.B. area. The June extension brought 96 additional trolley 'buses into service. In the following month, orders covering 114 trolley 'buses were placed by the Belfast Corporation Transport Department with the Associated Equipment Company and the General Electric Company. In July, the Johannesburg City Council recommended the placing of orders for 55 trolley 'buses, valued at 166,382*l.*, with British firms.

In addition to trolley 'buses, there has been renewed activity in connection with electric-traction vehicles generally, partly as a result of petrol restrictions due to the war. Quite early in the year, Partridge, Wilson and Company, Limited, announced a new type of 8-cwt. to 9-cwt. electric-battery vehicle designed for mass production, while Associated Electric Vehicle Manufacturers, Limited, received a large order, valued at 15,000*l.*, from Russia for electric-battery factory trucks. Since the outbreak of war this company has drawn up plans to increase the production of electric vehicles four times. There are said to be 5,000 electrically-driven vehicles in use in this country, and it is estimated that 100,000 vehicles now using petrol could be replaced by electrically-driven vehicles. The latter are particularly suited for delivery and collection work in large towns, the larger electric vehicles are extensively employed by municipalities. Electric vehicles are not likely to compete with private cars, owing to their limited range before recharging becomes necessary. Since the outbreak of war, however, the use of electric taxis in London has been advocated and it is claimed that these would show a running cost considerably below that of petrol-engined cabs.

British exports of electrical machinery fell to 26,931 tons, valued at 4,734,226*l.*, in the first eight months of 1939, from 30,048 tons, valued at 5,144,361*l.*, in the corresponding period of the previous year. As shown in Table III, opposite, exports were at a record level in the first quarter of the year, but declined quite considerably thereafter. This may have been partly due to the increasing pressure of armament work, particularly sub-contracting. The imports of electrical machinery into the United Kingdom are shown in Table IV, on the opposite page.

Table V, above, shows exports of generators, motors, converters and transformers from the principal exporting countries. British manufacturers definitely lost ground in 1939, their share of the total exports from the countries shown falling from 40·0 per cent. in 1938 to 34·4 per cent. in the first eight months of 1939. This decline was due mainly to increased exports from Germany, though United States manufacturers also improved their relative position. Attention has been drawn in this series in past years to the fact that Germany appears to have concentrated on export drives on individual groups of engineering products for comparatively short periods, and in 1939 it seemed quite likely that electrical-engineering products received particular attention. Nevertheless, the share of the market held by British manufacturers in that year was higher than in any previous year except 1938. Exports of control and switchgear from the United Kingdom and the United States are shown in Table VI, on this page. There was little change in the relative positions of the two countries between 1938 and 1939.

As regards individual products, it has already been noted that British exports of generators were higher in the first eight months of 1939 than in the

TABLE V.—EXPORTS OF GENERATORS, MOTORS, CONVERTERS AND TRANSFORMERS. (£000.)

	1932.	1933.	1934.	Per cent.	1935.	Per cent.	1936.	Per cent.	1937.	Per cent.	1938.	Per cent.	1939. (Jan.-Aug.)	Per cent.
United Kingdom	1,759	1,606	2,063	29·2	2,397	31·0	2,992	34·5	3,481	32·8	4,878	40·0	3,074	34·4
Germany	4,492	2,252	2,042	29·0	2,215	28·6	2,716	31·2	3,380	31·8	3,204	26·4	2,755	31·0
United States	1,405	926	931	13·2	1,175	15·2	1,227	14·1	1,701	16·0	1,598	13·1	1,315	14·6
Sweden*	658	649	801	11·3	878	11·4	838	9·6	894	8·4	916	7·5	732	8·3
Switzerland	501	623	511	7·3	577	7·4	536	6·2	786	7·4	1,002	8·2	607	6·9
France†	839	627	700	10·0	490	6·4	380	4·4	379	3·6	581	4·8	422	4·8
Total	9,654	6,683	7,048	100·0	7,732	100·0	8,689	100·0	10,621	100·0	12,179	100·0	8,905	100·0

* Includes some other unspecified electrical machinery and parts for electro-mechanical equipment, such as fans, vacuum cleaners, etc.
† Includes rectifiers.

TABLE VI.—EXPORTS OF CONTROL AND SWITCHGEAR FROM THE UNITED STATES AND THE UNITED KINGDOM. (£000.)

	1932.	1933.	1934.	1935.	1936.	1937.	1938.	1939. (Jan.-Aug.)
United Kingdom	1,260	889	1,101	1,431	1,765	2,038	2,827	1,563
United States ..	294	248	272	363	690	781	832	567
Total ..	1,554	1,137	1,373	1,794	2,455	2,819	3,659	2,130

corresponding period of the previous year. The figures were 7,412 tons, valued at 1,336,465*l.*, and 6,114 tons, valued at 1,097,988*l.* respectively. As usual, the Union of South Africa was the most important market, taking 2,028 tons in January-August, 1939, against 1,625 tons in the corresponding period of 1938.

In the case of motors, the total exports fell from 7,491 tons, valued at 1,147,010*l.*, in the first eight months of 1938, to 6,598 tons, valued at 1,036,554*l.* in 1939. In this case, India was the principal market, taking 1,126 tons, followed by South Africa with 1,112 tons. The growth in the Indian market is encouraging, since in previous years South Africa has taken a somewhat dangerously high proportion of the total exports. There has also been a steady increase in exports to foreign countries, which took 2,266 tons in the first eight months of 1939.

With regard to other descriptions of electrical machinery (mainly transformers and switchgear), the total exports fell from 16,443 tons, valued at 2,899,363*l.*, in the period January to August, 1938, to 12,921 tons, valued at 2,361,207*l.* The principal market in this case was South Africa (3,783 tons in 1939), followed by India (2,891 tons), New Zealand (1,246 tons), and Australia (1,159 tons).

The war should undoubtedly provide a very good opportunity for British manufacturers to increase their hold on world markets. For some time Germany has been their principal competitor, and in 1938 Great Britain and Germany together accounted for about two-thirds of the total exports of the countries shown in Table V. In 1938, just over half the total German exports, 10,970 metric tons out of 21,570 metric tons, went to overseas countries from which Germany is likely to be cut off by the blockade. The most important overseas markets were Brazil (1,825 metric tons); Japan (1,741 metric tons); India (1,546 metric tons); Argentina (1,309 metric tons); South Africa (842 metric tons); China (643 metric tons); and Chile (609 metric tons).

NON-OSCILLATING PETERSEN COIL.

THE interconnection of power stations necessitates the provision of means for quenching short-circuits to earth when a fault occurs; and where the neutral is unearthed, as is the case on most European systems, an effective method of doing this is to use the arc-suppression coil which was invented by Petersen in 1916. This device enables the majority of earth faults to be limited to the stage of flash-overs of short duration, re-ignition of the arc and the recurrence of the over-pressures connected with it both being prevented. While the principle laid down by Petersen has remained unaltered, changes have been made in the design of the coils themselves, owing to the necessity for adapting them to the characteristics of the different systems. It may be recalled that in these coils the iron core forming the limbs is divided into a large number of sections which are separated by relatively small air gaps. These gaps must be kept small in order that the magnetism shall not produce additional losses in the windings and other metal parts, especially the yoke. The height of the individual packets of laminations is usually about 70 mm. to 80 mm., and they are separated by insulating plates. To prevent these units from becoming charged when the winding is earthed at one end, they are connected by leads and the built-up limbs and yokes are firmly secured together by bronze tie-rods.

The most important part of an arc-suppression coil is the winding, especially with the wide range of regulation usually required. For instance, if the current is to be adjustable within a range of 1 to 4, this means that, with a constant pressure across the coil during the short-circuit to earth, the number of turns must be variable in the ratio of 1 to 2. In other words, when the current is a maximum, half the turns must be cut out. To cut out such a large section of the windings provides a difficult problem for the designer and must be considered from three aspects: First, the distribution in space of the magnetomotive forces of the winding in relation to that of the reluctance of the iron circuit; second, the heating of the coil; and third, the pressure conditions in the latter. In order to meet these conditions, Messrs. Oerlikon, Limited, whose London office is at Victoria House, Southampton-row, W.C.1, have designed a new type of winding for adjustable arc-suppression coils, in which the cutting-out of sections is, as far as possible, avoided.

The simplest arrangement for an adjustable winding of this description with a current regulation of 1 to 4 is shown in Figs. 3 to 5, on page 200. As will be seen, the single-phase arc-suppression coil depicted has two limbs on each of which is a similar winding. These are first connected in parallel, as shown in Fig. 3, then in series-parallel, as in Fig. 4, and finally, in series, as in Fig. 5, when varying the current from the maximum to the minimum value. In the process, the effective number of turns is altered in the ratio of 1 to 2. The coils can, of course, be built for smaller ranges of regulation, the ratio 1 to 4 being the upper limit. In order to keep the distribution of the magnetomotive forces of the winding always symmetrical in relation to the iron cores over the whole length of the latter, the individual windings are connected in parallel, as shown in Fig. 6, which is a diagram of an arc-suppression coil with 16 steps for adjustment. During regulation, the curve representing the distribution of the magnetomotive forces along the limb is a broken line. This is due to the forces being concentrated at the end of the limbs owing to part of the winding being in series. As a result, the lines of force are forced over the air gaps, resulting in small additional losses. In most cases, an arrangement is called for which will ensure uniform distribution over the different notches of the switch, a condition which entails the concentration of the tappings at the ends of the limbs. The heat losses do not amount to more than 1 per cent., either on continuous operation or for two hours' service, and the tanks are either provided with welded-on radiators or are of the smooth-surface type. The copper section of the winding is varied in steps along the whole length of the latter, and during the whole regulation process the total weight of copper and the total surface of the coils are available for reducing the heating due to losses and for transmitting the heat to the oil. The constructional details to meet the pressure conditions are in accordance with modern transformer design. Generally speaking, paper insulation is used throughout, protective rings being fitted at the ends of the windings to ensure good pressure distribution.

The parts of the windings which have to be cut out for regulation purposes are usually designed as concentric coils which are stepped in layers and arranged over a base winding of uniform diameter. The cutting out of the regulating turns can be effected at the beginning, in the middle, or at the end of the whole winding. In each case, however, the open portion of the winding cutout is close coupled with the main winding, both inductively and from the capacity point of view. As large open sections of windings constitute possible points of reflection for oscillations in the immediate neighbourhood of the main winding, they possess pressure characteristics that have to be taken into account when insulating both the windings and the tappings. Thus, special care is taken to connect all open ends of windings subjected to the test pressure metallically, as the slightest disturbance at one point may give rise to oscillations at the open end and cause otherwise inexplicable flash-overs. It is claimed that the new arrangement adopted for the winding marks a considerable advance in this connection, since no open portions of winding are cut out and the winding of the whole limb is always in circuit. The portions of the windings of the two limbs which are in parallel for the time being are well apart and of identical design from an electromagnetic point of view.

Under normal conditions, regulation is effected by a tapping switch, which is operated when there is no short-circuit to earth in the system. Where switching on load is required, however, switches similar to those employed on regulating transformers can be used. The equipment has a plate-type selector and a separate load switch, working in conjunction with resistances. Fig. 1, page 200, shows a 5,650-kVA arc-suppression coil at the Toes substation, which is part of the 150-kV system of the Nordostschweizerische Kraftwerke, Switzerland, while Fig. 2 is an illustration of the coils themselves. These are designed for a current range of 25 amperes to 65 amperes on the two-hour rating.

THE HENRY SAXON SNELL PRIZE COMPETITION.—The subject given for the essays in the 1939 competition for the Henry Saxon Snell Prize, held under the auspices of the Royal Sanitary Institute, was "Improvements in the Construction or Adaptation of Sanitary Appliances." Six essays were received, but the adjudicators were of the opinion that none of them was of sufficient merit to justify the award, and the Council has, therefore, decided to withhold the Prize on this occasion. Nevertheless, it has been decided to award the sums of 10*l.* 10*s.* to Mr. A. V. Pimble, of Newcastle, Staffs., and of 5*l.* 5*s.* to Mr. F. J. Hedgecock, of Addington, South Croydon, in recognition of the care taken by them in preparing their essays and the accompanying drawings.

NOTES ON NEW BOOKS.

Principles of Metallography. By PROFESSORS ROBERT S. WILLIAMS and VICTOR O. HOMERBERG. Fourth edition. London: McGraw-Hill Publishing Company, Limited. [Price 23*s.*]

A VAST amount of literature has been published during recent years relating to various aspects of metallurgy, and modern developments necessitate the periodical appearance of revised editions of volumes dealing with the fundamentals of the subject. This publication, the first edition of which appeared in 1919, is one of the International Chemical Series and is devoted to a study of the basic principles of physical metallurgy. During the course of the various editions, the text has undergone considerable revision and much new material has been incorporated. Modern theories are given prominence and a new chapter, contributed by Professor Morris Cohen, has been introduced, dealing with "The Plastic Deformation and Annealing of Metals." This section is of special interest, for, although the situation existing along the grain boundaries during the plastic deformation of polycrystalline metals is not clearly understood, the text indicates how this form of deformation is the integrated result of the combined deformation of the individual grains, a phenomenon which is illustrated diagrammatically by the cold-rolling process. A summary is given of the current theories relating to the causes of work-hardening in metals, including those of the amorphous-metal, fragmentation, and the lattice-distortion types. The three theories suggest the existence of a highly disorganised condition along the twinning planes and grain boundaries, such that the capacity for further slip is decreased, but that the resistance to further slip tends to increase. The far-reaching importance of the recrystallisation and growth processes in metals is emphasised, and the illustrations and microphotographs are a notable feature of the volume.

Human Relations Manual for Executives. By CARL HEYEL. London: McGraw-Hill Publishing Company, Limited. [Price 12*s.* 6*d.*]

NOWHERE has the importance of superseding dictatorship methods by reciprocal confidence and understanding been better appreciated than in industrial undertakings. Mr. Carl Heyel, as manager of the Conference Planning Division of the American Management Association, has been well placed to note and record for the interest of industrialists a host of schemes, directed to this end, which have been proved workable by progressive American concerns. Suggestions, not always closely related, follow each other throughout the book in such rapid succession that the text is rendered somewhat too disconnected for steady reading, but the associated ideas have been collected as far as possible into suitable chapters, with bibliographical references to the sources of fuller particulars. At the end of each of the nine chapters is given a list of "application check points," consisting of questions designed to enable the reader to compare what he has just read with the methods employed in his own business. This may seem naïve; but it is probable that few industrial executives who conscientiously study the points made will fail to receive some stimulus or to be reminded of some way in which the relations between master and man can be improved in their own organisations. It is rather unfortunate that the author has seldom thought it necessary to indicate whether a particular idea has been applied in an engineering shop, a bank, or a chain of drug stores. Although written primarily for the perusal of executives, the book should appeal also to any progressively-minded employee who has access to a suggestion box.

British Railways To-Day. By DR. K. G. FENELON. London and Edinburgh: Messrs. Thomas Nelson and Sons, Limited. [Price 2*s.* 6*d.* net.]

THIS book is No. 39 in Messrs. Nelson's "Discussion" series and, on the whole, is an interesting and informative work, although parts of it would bear amendment. The best chapters are those entitled State Control, Railways and their Clients, and Railways and the Roads; these set out both sides of the case very fairly and are in pleasant contrast to the one-sided arguments frequently offered to the public. The author makes it clear that both parties in the Road *v.* Rail controversy are defendants as well as complainants, and he puts a shrewd finger on a major weakness of the railways when he discusses branch-line services. If it be correct, as he states, that "the station rate-books contain among them several tens of millions of entries," it is not surprising that the railways should want to alter such a state of affairs; but it is certainly curious that they should have been so long in thinking of it. The student of transport problems will find much of value in the discussion of wagon capacities and ownership; again, very impartially presented,

but with the unavoidable conclusion that the combination of private ownership and low capacity of wagons is not the best for the economical conveyance of bulk cargoes. The question might be asked, why the author stops at the 20-ton wagon; if the use of this size permits a reduction of from 5 per cent. to 10 per cent. in freight charges, it might be supposed that the practicability of standardising still larger sizes might be worth re-examination. From the practical point of view, the least satisfactory section is that purporting to deal with "Some Problems of Railway Operation," which is hardly equal in quality to the rest of the book. It would be helpful if the hypothetical "working time table" could be compared with an actual working time table of a branch carrying similar traffic, and if a graphic time table were then constructed from the latter, for comparison with the example given. The remarks on the carriage roster are inadequate, a criticism which applies even more forcibly to the dismissal of locomotive operation—the most important and expensive item of all—in a mere three-quarters of a page.

Electrical Technology. Fourth edition. By PROFESSOR H. COTTON, D.Sc. London: Sir Isaac Pitman and Sons, Limited. [Price 12*s.* 6*d.* net.]

FIRST published in 1924, this excellent work has now reached its fourth edition. Among the numerous competent text-books on electrical technology which are now available, this deservedly occupies a high place. In standard, it takes the student through a second-year course, and, therefore, provides ample preparation for Higher Certificates and pass degrees. The excellence of treatises devoted to what may be called standard knowledge is largely qualified by the arrangement of the material. Dr. Cotton has continuously improved his book in this direction. In the new edition, polyphase circuits are treated at an earlier stage, to enable polyphase machines to be considered instead of only single-phase machines. The polyphase commutator motor is now included, while illumination is placed in a new section. The book can be thoroughly recommended.

Road Accidents. By SIR ALFRED HERBERT, K.B.E. Published by the author.

ALTHOUGH the latest report on road accidents, issued by the Ministry of Transport, shows that the total of deaths during January was 536 less than in the preceding month, it was still, at 619, a sufficiently serious testimony to the dangers of the roads, and in marked contrast to the almost complete safety of British railway travel. In the past, there has been a great deal of criticism of the carelessness of motorists by those who obviously are neither motorists themselves, nor acquainted with the elementary laws of motion, which prevent even the most careful motorist from doing the impossible in the presence of culpably negligent pedestrians. Sir Alfred Herbert writes, in this pamphlet, as a pioneer motorist and as an engineer, and it is not too much to say that, if his advice were to be followed to the letter by motorists, cyclists and pedestrians, the road accidents reported to the Ministry of Transport would speedily become too few and trivial to justify the issue of monthly returns. Copies of the pamphlet can be obtained on application to Sir Alfred Herbert, K.B.E., Dunley Manor, Whitchurch, Hants.

Rules for the Construction, Testing and Scantlings of Fusion-Welded Steel Pressure Vessels. Manchester: The Vulcan Boiler and General Insurance Company, Limited.

IN ENGINEERING of August 26, 1938, we reviewed the *Schedule of Examinations and Tests of Welded Drums*, which had been drawn up by the Associated Offices Technical Committee, representing the British Engine, Boiler and Electrical, National Boiler and General, Scottish Boiler and General, and Vulcan Boiler and General Insurance Companies. Since that time, in response to the expressed desire of many users of welded pressure vessels for a definite code of construction, the Technical Committee has continued its work, and has now produced a code of *Rules*, a copy of which we have received from the last-named company. The code covers all three of the recognised classes of such pressure vessels, and is intended to be used in conjunction with the *Schedule* before-mentioned. It is supplemented by charts showing the value of the constant K for semi-elliptical dished ends, and the limiting thickness and diameter above which heat treatment is required for the relief of stresses. Diagrams are also given showing approved methods of attaching stand pipes by welding and of connecting end plates to cylindrical shells, and the form of test plate for Class II vessels.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—Mr. J. P. Hogan, of New York, was elected President of the American Society of Civil Engineers, for 1940, at the annual meeting of the Society, held recently in New York.

THE KADENACY ENGINE.

IN June, 1937, an article* was published in our columns by Professor S. J. Davies in which the proposals of M. Michel Kadenacy for improving the efficiency of engines operating on the two-stroke cycle were examined. In this article, it was stated that the basic contribution that M. Kadenacy had made to engine design was his discovery that, immediately on rapidly opening the exhaust ports of an engine during the expansion stroke, there was an urge or impulse in the gases within the cylinder to escape very rapidly, leaving behind them a depression. It was further stated that, as a supplementary improvement, M. Kadenacy had found it possible to utilise the momentum of the exhaust gases leaving the cylinder to prolong the period of time during which a vacuum might prevail in the cylinder behind the exhaust gases. Expressing these statements in another way, they amount to a claim that the efficiency of engines operating on the two-stroke cycle can be improved simply by altering the valve timing and port areas in such a way that advantage is taken of the depression in the cylinder referred to to secure an enhanced charge, and that to obtain the maximum increase in efficiency, the exhaust system should bear a definite relationship to the valve timing. Since the article referred to appeared, there has been a considerable amount of correspondence in our columns regarding the Kadenacy system. We do not propose to refer to this correspondence at the moment, beyond stating that, while the improvement in efficiency in engines to which the system is applied is not seriously disputed, there is a marked divergence of opinion whether these improvements result from the actual creation by the action of the exhaust gases of a depression below atmospheric pressure in the cylinder, or from some other cause that has not yet been elucidated. That they are not merely due to taking advantage of the well-known exhaust-pipe effects appears to be proved simply by their magnitude, putting aside Dr. Davies' statement in his original article that he had obtained an enhanced efficiency by applying Kadenacy timing to an engine without an exhaust pipe.

The simplicity of the Kadenacy system is shown by the fact that it can be employed on the majority of existing designs without the necessity for basic alterations. A number of such conversions have been made in the Slough research laboratories of Messrs. Armstrong Whitworth Securities Company, Limited, Buckingham-avenue, Slough, Bucks, with very striking results, but the best results are naturally only secured with engines designed *ab initio* to operate on the system. Until recently, the only engine designed in this way was the Petter super-scavenge model, described in ENGINEERING, vol. 146, page 10 (1938). This engine has been the subject of further research, and the remarkable results obtained formed the subject of an article by Professor Davies on page 43, *ante*. Two further engines, which may be described as prototype designs, have recently been built and tested.

The first of these engines with which we propose to deal, a single-cylinder model, is illustrated in Figs. 1 to 5, Plate X, and Fig. 8, on page 196. It is designed for general industrial purposes, and for this reason a heavy flywheel is fitted and the crankshaft is extended to carry a pulley at either or both ends, as shown in Fig. 3. A starting handle is fitted to one end of the shaft. No outside bearing is necessary, when a pulley is fitted beyond the flywheel. The cylinder bore is $2\frac{5}{8}$ in., and the piston stroke is $4\frac{1}{2}$ in., giving a capacity of 437 cc. The engine is normally supplied to run at a constant governed speed of 1,000 r.p.m., at which a rated output of 5 brake horse-power is obtained. The brake m.e.p. at the normal rated output is 73·9 lb. per square inch, and at this rating there is an overload margin of 15 per cent. for one hour. The remarkable brake m.e.p. obtained is, perhaps, best brought out by comparison with four-stroke engines of approximately similar cylinder dimensions already on the market.

The system of working is extremely simple. Air is drawn into the cylinder directly from the atmosphere, passing first through an absorption-type straight-through silencer, shown on the left in Fig. 4, and also in Fig. 5, then into the air passage in the main casting and thence into the cylinder through the ports in the liner. The exhaust is controlled by a mechanically-operated overhead valve, situated in the centre of the cylinder head, the valve head forming the main portion of the upper surface of the combustion chamber. As also shown in these figures, the latter is symmetrical in form and consists mainly of a spherical recess in the piston top with partly conical sides, the base of the inverted cone being formed by the exhaust valve head. The top surface of the piston outside the combustion space proper is slightly conical and corresponds to a similarly shaped surface on the underside of the cylinder head. The effect of this is that as the piston approaches its top dead centre there is produced a certain inward movement of the combustion air between these surfaces. The inlet ports are shown in Fig. 8, and it will be seen that they are tangentially arranged, causing a pronounced rotational swirl of the incoming air, which movement continues during compression. The combination of these two air movements creates in the combustion chamber a resultant helical movement towards the centre, which is beneficial in promoting good fuel distribution and combustion. The fuel injector is carried in the cylinder head and is placed so that the spray enters the combustion space tangentially and with a slight downward angle towards the centre of the space. The injector nozzle, which is shown on the left in Fig. 4, has a single central hole of relatively large size.

The main frame, shown in Figs. 3 and 4, is a single iron casting forming the cylinder and crank chamber, and carrying the inserted water-cooled liner and the three main bearings for the crankshaft. These bearings are of white-metal lined bronze and are carried in solid housings, the two outer ones being spigotted into the sides of the crank chamber. The outer ends of these bearings are fitted with sealing rings to prevent leakage of lubricating oil, as shown in Fig. 3. The crankshaft is a solid steel forging, and is fitted with balance weights. The connecting rod is also a solid steel forging, of circular section. The two-bolt big end is fitted with bronze bearing shells, white-metal lined, and the small end has a fixed solid bronze bush. The rod is drilled through its centre for the passage of pressure lubricating oil to the small-end bearing. The piston is of cast iron, and the hardened-steel gudgeon pin is of the fully floating type. There are five rings on the piston, the top one being a double ring with a conical jointing surface between the two parts. The other four consist of three normal pressure rings and one scraper ring.

The cast-iron cylinder head is of simple and strong form, as it embodies only the central exhaust valve and one injector. It is held down by six studs, and the joint between it and the cylinder block is made by a plain flat copper gasket. The valve rocker, shown in Fig. 3, is mounted on the top of the head and is enclosed in an oil-tight cover. The valve push rod, which is operated by a cam on the crankshaft, as shown in the same figure, passes through a tube which is sealed against oil leakage at the top by a simple gland fixed on a side extension cast with the cylinder head. The exhaust valve, of alloy steel, is of large diameter, and the seating is masked with the object of creating rapid development of effective area on opening. The exhaust cam is mounted adjacent to one of the side bearings, and the housing for the bottom guide of the push rod is formed solid with the crank chamber.

The fuel-injection equipment is of C.A.V. manufacture. The pump is mounted on a horizontal facing on the crank chamber just above the centre of the crankshaft, on which the fuel cam is fixed, as shown to the left in Fig. 3. Below the crankshaft, and mounted on an extension of the lubricating-pump spindle, there is a centrifugal governor which, by means of a vertical spindle, operates on the control rod of the fuel pump. The arrangement will be clear from Fig. 3. The whole pump and control gear is neatly enclosed by an aluminium cover through which the fuel-delivery pipe and the hand-operating rod project. The delivery pipe is hidden by the intake silencer in Fig. 1. An adequate C.A.V. filter, clearly visible in this figure, is provided in the fuel-supply pipe to the injection pump. Forced lubrication is provided to all the important parts. A sump below the crank chamber provides the necessary oil capacity, and from this a small gear-type pump, mounted in a housing machined in the vertical side wall of the crank chamber, as shown in Fig. 3, and driven with the governor by a gear wheel on the crankshaft, draws through an inlet passage drilled in the solid casting. A similar delivery passage leads directly to the adjacent main bearing, and from there holes drilled in the crankshaft lead to the connecting rod big-end bearing and to the main bearing on the farther side of the crank. In a similar manner, drilled holes from the first main-bearing housing lead to the cam rollers and guides for the exhaust valve and fuel pump. The third, or outer, bearing for the crankshaft is lubricated by oil caught in a large-capacity trough formed in the bearing housing, and shown in Fig. 3. The valve rocker on the cylinder head is also lubricated by pressure feed through a pipe leading from the crank chamber adjacent to the main bearing up to the side of the cylinder head. The return oil from the top gear flows back to the crank chamber down the tube surrounding the push rod. Ample water-cooling space is provided round the cylinder liner, and the water connection to the cylinder head is made by drilled holes in the top of the crank chamber and the bottom of the cylinder head. Three of the holes are fitted with brass tubular dowels, which serve to locate the cylinder head. One of these is placed

* The Characteristics of Engines of Kadenacy Design. ENGINEERING, vol. 143, page 685 (1937).

directly under the fuel injector, so that this is well cooled. The water outlet from the cylinder head is taken off at the highest point, thus ensuring absence of air pockets.

The engine is started by hand, and in order to facilitate this operation, provision is made in the air-inlet system to obtain the advantage of crank-chamber compression, giving some small measure of pressure charging of the cylinder during the period of hand turning. This is done by means of a rotatable valve built into the air inlet branch, by which the atmospheric air inlet is blanked off and the space around the inlet ports in the liner is connected to the crank chamber. The rotatable valve can be seen in Fig. 4, and is shown to an enlarged scale in Fig. 5. An automatic non-return valve, shown in Fig. 8, is fitted in the end of the rotatable valve, and this, on the upstroke of the piston, admits atmospheric air into the crank chamber. On the down stroke of the piston, this valve closes, and lightly compressed air from the crank chamber flows into the cylinder when the inlet ports are uncovered. This ensures a good charge of air with a satisfactory compression, and, in consequence, ready firing in the cylinder. As soon as the engine is running at a fair speed, the rotatable valve is turned back so that the air port spaces are connected directly to the atmosphere and isolated from the crank chamber. A relief valve, shown opposite the main bearings in Fig. 4, controlling the maximum pressure of the lubricating oil, is provided, and there is also fitted on the exhaust-side inspection door a handy oil-filling cap embodying a gauze filter. This cap is also shown in Fig. 4. Adjacent to this there is a dip stick for checking the level of the lubricating oil in the sump. Ready inspection of the main working parts is provided for by openings in both sides of the crank chamber.

As stated above, the exhaust system is one of the elements that can exert an influence on the performance of a Kadenacy engine. There is no difficulty in matching up the exhaust system to the engine with any convenient arrangement of exhaust pipe and silencer, and in many cases, the pipe may be vertical with the silencer at some point in the vertical branch. A neat alternative arrangement is shown in Fig. 2, Plate X, the pipe in this case being coiled round the flywheel. This particular view shows an engine on test coupled to a Heenan and Froude dynamometer, and fitted with measuring instruments.

Mention has been made of the fact that the engine described is designed to run at a constant governed speed of 1,000 r.p.m. The performance characteristics under varying load in these circumstances are given in Table I, while curves of maximum cylinder pressure, exhaust temperature, percentage heat lost to water, and fuel consumption, are reproduced in Figs. 9 and 11. It will be appreciated that, for an engine required for general industrial purposes, it is essential that a satisfactory performance should be secured over a wide range of speeds, and it is therefore of particular interest to note the performance of the engine described

TABLE I.

B.m.e.p.,lb. per sq. in.	73·9	55·92	36·95	18·97	85·0
Proportion of b.m.e.p.	1·0	0·75	0·5	0·25	1·15
B.h.p.	5·0	5·75	2·5	1·25	5·75
Fuel per b.h.p.-hour, lb.	0·405	0·420	0·476	0·702	0·423
Exhaust temp., deg.C.	250	234	210	182	260

TABLE II.

R.p.m. ..	450	600	700	800	900	1,000
B.h.p. ..	2·3	3·1	3·65	4·18	4·73	5·2
B.m.e.p., lb. per sq. in.	75·6	76·3	77·1	77·2	77·6	76·7
Torque,lb.-ft.	26·85	27·10	27·30	27·40	27·62	27·30

when the governor is disconnected, and the speed is controlled by the load. The most important characteristic at varying speeds is, of course, the torque. The characteristics of the engine when running with a fixed fuel setting on varying load are given in Table II, while curves of brake horse-power, brake m.e.p., and torque, on a speed base, are reproduced in Fig. 10. The manner in which the torque is maintained throughout the speed range is very striking.

Actually, two six-cylinder engines of the two-cycle type, operating on the Kadenacy system, have been built by Messrs. Armstrong Whitworth Security Company, Limited. The first of these engines, shown in Fig. 12, opposite, was a purely experimental model and may be referred to as the prototype, while the second, which may be referred to as the commercial type, embodied a number of minor modifications indicated as advisable by the experience gained with the prototype. The main differences in the two models are that in the prototype, the fuel injector was horizontal and was located below the exhaust passages on the back of the engine, as viewed in the photograph reproduced in Fig. 12, whereas in the commercial model the injector is located, with the exhaust passages, on the other side. A further difference is that the

KADENACY SYSTEM ENGINES.

Fig. 8.

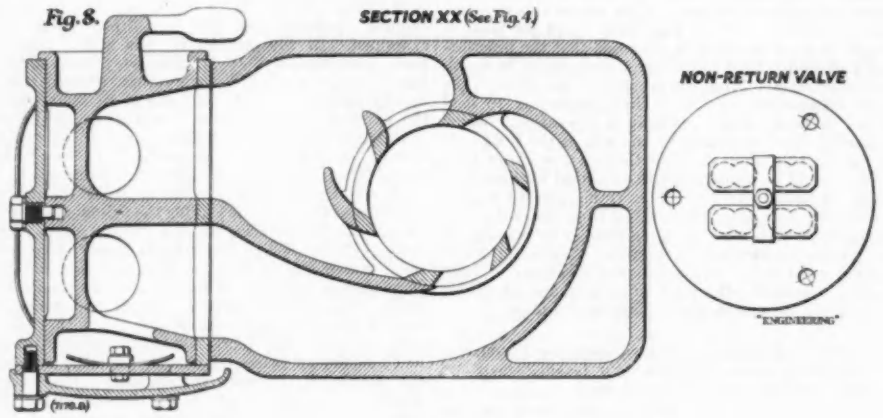


Fig. 9.

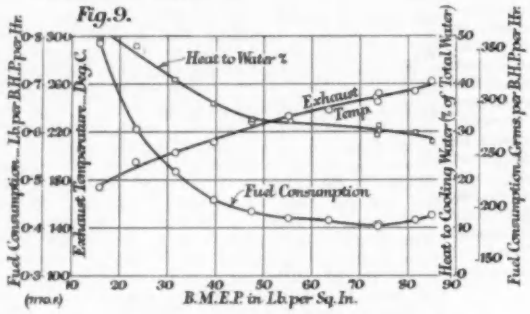

Heat to Water %
Exhaust Temps
Fuel Consumption
Fuel Consumption—Lb. per B.H.P. per Hr.
Exhaust Temperature—Deg. C.
Heat to Cooling Water (% of Total Water)
B.M.E.P. in Lb. per Sq. In.
(7170.1)

Fig. 10.

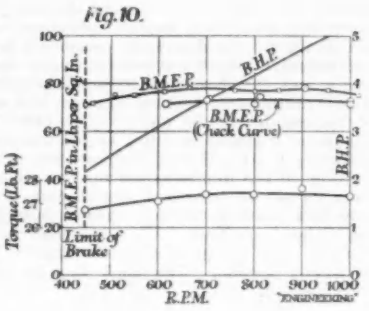
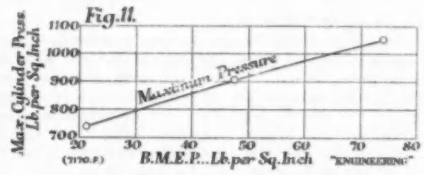


Fig. 11.



blower on the prototype model was located on the exhaust side and driven by a chain from a sprocket on the crankshaft outside the flywheel, while, on the commercial model, it is built on to the side of the crank chamber and driven by a layshaft forming an extension of the circulating-pump shaft. Again, on the prototype engine, the air-inlet piping and manifold between the blower and the cylinders was external to the crank-chamber, but in the commercial unit these are incorporated in the chamber casting itself. Other differences are that the other auxiliaries, in addition to the blower, are disposed somewhat differently on the commercial unit with a view to giving a neater and cleaner design. The two engines are of the same dimensions, and as none of the differences referred to is of basic importance, we propose to confine our description to the commercial engine. This is illustrated in Figs. 6 and 7, Plate X, and Figs. 12 and 13, opposite.

The cylinder bore is 100 mm. (3$\frac{15}{16}$ in.) and the piston stroke is 150 mm. (5$\frac{29}{32}$ in.), giving a capacity of 7·07 litres (344 cub. in.). Like the single-cylinder engine already described, the six-cylinder engine was designed for general industrial purposes. The rated output is 118 brake horse-power at 1,200 r.p.m., and the brake m.e.p. at this output is 90 lb. per square inch. At this rating, there is an overload capacity of 10 per cent. for one hour. It has already been mentioned that this engine is fitted with a blower, in which it differs from the single-cylinder model, but it closely resembles the latter in many other respects. The arrangement of the combustion space, injector, and exhaust valve, for example, is practically identical in the two engines. The blower, which is of the Roots type, is shown on the right in Fig. 7, and it will be seen that it delivers into an air manifold formed in one side of the cylinder block, passages at the end of the cylinder permitting the air to pass also into the corresponding manifold on the other side of the engine. From the two manifolds, the air passes into the cylinders through rings of ports uncovered by the pistons at the bottom of their stroke. The exhaust valve being similar to that in the single-cylinder engine, need not be described again, but the short and straight exhaust passages may be noted. Although not shown in the illustrations, the air ports in the cylinders are tangentially arranged as in the single-cylinder engine. The injector nozzle has two holes of relatively large size, as compared with one hole in the single-cylinder engine nozzle.

The main frame, shown in Figs. 6 and 7, is a single iron casting carrying the six inserted water-cooled liners and the seven main bearing housings for the crankshaft. As shown in Fig. 7, the bottom face of the crankcase is situated a little distance below the centre line of the crankshaft, which distance is sufficient to accommodate the cast-steel main-bearing caps with their studs and nuts. The bearings themselves are of steel, white-metal lined, the shells being located circumferentially and end-ways by substantial dowel pins. The bearing next to the flywheel, at the driving end, acts as the thrust bearing. Oil leakage at this end of the crankcase is prevented by a large-diameter oil thrower on the solid coupling flange of the crankshaft, shown in Fig. 6, and a helical groove, forming a labyrinth, turned in the close-fitting bore of the end cover, through which the coupling flange projects. At the other end of the crankshaft a somewhat similar arrangement to prevent oil leakage is provided; in this case, the helical labyrinth is formed on the outside of an extension to the crankshaft, which is provided for taking a barring handle.

The six-throw crankshaft is a solid-steel forging and carries the flywheel at the driving end, and a vibration damper at the free end, which prevents the occurrence of any serious torsional oscillations due to critical speeds. As shown in Fig. 6, a gear pinion is fitted between the damper and the first bearing journal, for driving the timing gear, the lubricating-oil pump and other auxiliaries. The connecting rods are solid steel forgings, the rods being of circular section with a large drilled hole up the centre for lightness. The big ends are of the two-bolt type, fitted with steel shells white-metal lined. The small-end bearings are of the needle-roller type. Forced lubrication is applied to the big-end bearings by means of holes drilled through the crankshaft. The small-end bearing is sufficiently lubricated by splash. The pistons are of aluminium-alloy, and the gudgeon pins, of hardened steel, are fixed by a key and a locating pin. There are six piston rings, of which four are above the gudgeon pin and two are close to the bottom edge. The two top rings are of the taper-sided type, the bottom ring is a plain chamfered-edge scraper, and the remaining three are plain pressure rings. All the rings have scarf joints of 45 deg.

The one-piece cast-iron cylinder head covers the whole six cylinders and embodies the six exhaust valves, six injectors, six valve-operating levers and the camshaft with six exhaust cams. The fulcrum bearing for the valve levers and the bearings for the camshaft are force lubricated and the rollers on the valve levers are of the ball-bearing type. The whole top gear is neatly enclosed by a side and a top cover, and provision is made to drain all surplus lubricating oil back into the crank chamber. A jet of lubricating oil plays directly on to the contact point between the cam and the roller

KADENACY SYSTEM ENGINES.

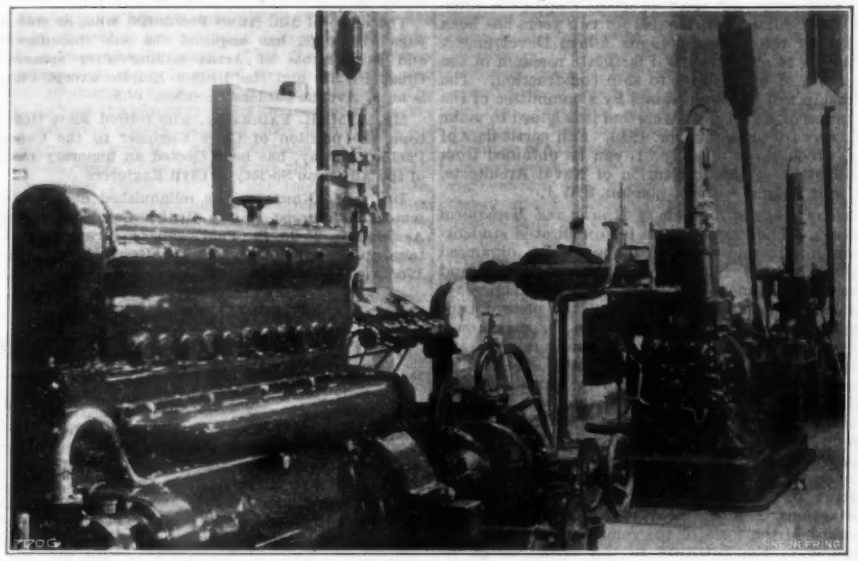
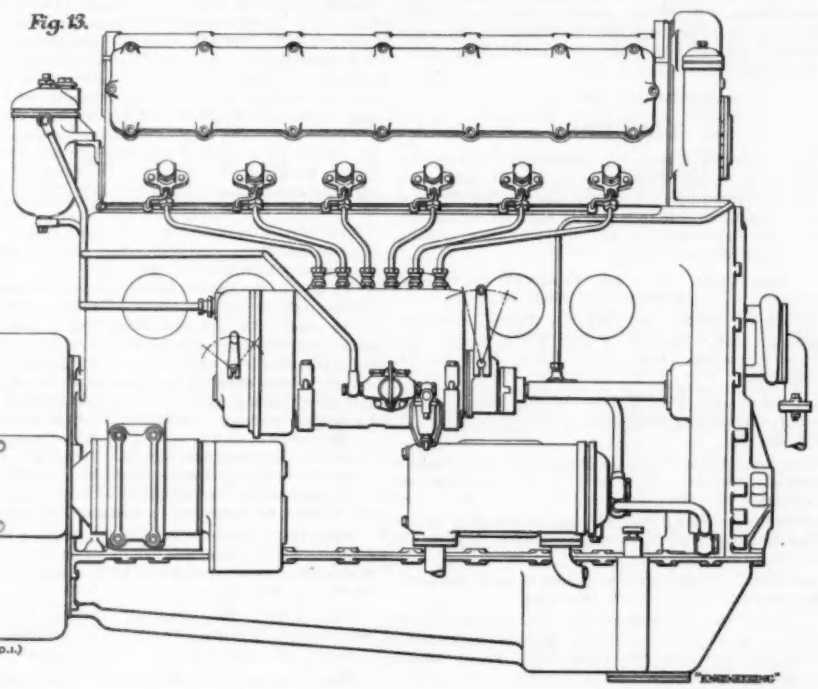
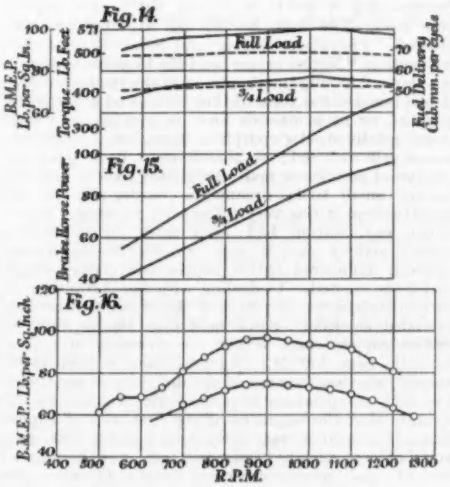
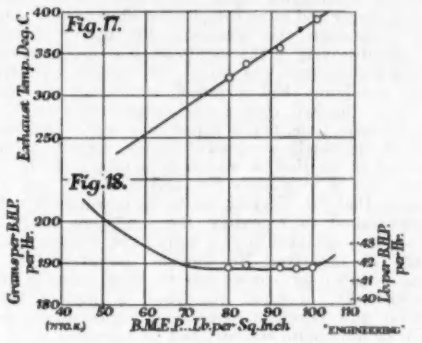


FIG. 12. ENGINES IN TESTING LABORATORY.







on each valve lever. The drive to the overhead camshaft is by a double-roller chain from the fuel-pump layshaft, which itself is driven by gears through a single idler wheel from the crankshaft. The gear train can be seen to the right in Fig. 6. The chain drive is provided with an adjustable idler wheel for setting the correct tightness, as well as a steadying block on the long side of the drive to prevent vibration. The exhaust valves, of alloy steel, are of large diameter and, as in the single-cylinder engine, the seating is masked, with the object of creating rapid development of effective area on opening. The cams, of hardened steel, are keyed on the overhead shaft, which is carried in seven bearings formed in the cylinder-head casting. The caps for these bearings are part of the main cover over the top gear and the bearings are fitted with bronze shells.

The fuel-injection equipment is of C.A.V. manufacture, and, as shown in Figs. 7 and 13, the six-plunger pump is mounted on the side of the crankcase at the exhaust side and immediately below the injectors; the delivery pipes are, therefore, quite short and direct. The pump itself is a standard unit fitted with the usual timing and adjustment device, and combined idling and maximum-speed governor. A fuel filter, shown above the flywheel casing in Fig. 13, is provided on the supply pipe to the pump. The gear-type lubricating pump is carried below the main-bearing cap at the forward end of the engine, as shown in Fig. 6, and is held in position by the studs securing that cap. It is driven by a single gear wheel, which meshes with the timing pinion on the crankshaft. A large sump bolted to the underside of the crank chamber provides the necessary oil capacity, and the pump draws from this through a vertical pipe, extending downwards nearly to the bottom of the sump, into a filter box carried on a separate cover let into the underside of the sump. The delivery oil passes first through the side of the crank chamber to a relief valve fitting, accessible on the outside, from which it passes through external pipes to a second, Bosch-type, filter box, then to the water-cooled oil cooler, shown to the right just above the sump in Fig. 13, and finally to the main distributing passage cast in the crank-chamber, somewhat above the level of the crankshaft. From this passage, which can be seen below the air manifolds in Fig. 7, downwardly-inclined drilled holes lead to the individual main bearings and by drilled holes in the crankshaft to the connecting-rod bearings, a further external pipe taking a feed to another distributing passage cast in the cylinder head supplying the valve gear and camshaft bearings.

Ample water cooling space is provided around the cylinder liners, and from this space holes drilled through the top of the crank chamber and the bottom of the cylinder head lead into the cooling spaces around the exhaust valves and fuel injectors. As in the single-cylinder engine, a number of these connecting holes are provided with brass tubular dowels, which serve to locate the cylinder head. Positive water circulation is given by a small centrifugal-type pump, shown in Fig. 13, mounted on the forward end cover and driven by gears through one idler wheel from the timing pinion on the crankshaft. A by-pass pipe is provided from the main outlet manifold pipe on the cylinder head to the pump suction pipe, so that, by means of a regulating valve in the by-pass pipe, the temperature of the inlet water can be maintained at a favourable level. The exhaust manifold attached to the cylinder head is of normal form and dimensions, and is fitted with a silencer of simple design, the whole silencing system being matched up to the engine, as for the single-cylinder model. Although means for turning the engine by hand are provided, the normal method of starting is by electric motor. This motor is of the usual motor-vehicle type, with a driving pinion which engages at starting with a rack on the circumference of the flywheel. Provision is made also for mounting and driving a dynamo. Three-point suspension of the whole engine unit is adopted, there being a carrying bracket at each side of the flywheel housing, attached to the crank chamber, and a swivel bearing on an extension of the forward end cover, at the level of the crankshaft. The chief characteristics of the engine are shown by the curves reproduced in Figs. 14 to 18, but it may be emphasised that these curves were taken with the prototype engine. The torque and b.m.e.p. curves for full and three-quarters load are shown in Fig. 14; these curves are taken with the blower in normal operation, the pressure of the air supply by the blower being 2 lb. per square inch. By way of interest, however, b.m.e.p. curves are also shown in Fig. 16, but with the blower removed and the air supplied to the engine by natural aspiration. In this figure the upper curve was taken with a fuel setting of 69 cub. mm. per cycle at 900 r.p.m., and the lower curve was taken with a fuel setting of 50 cub. mm. per cycle at 900 r.p.m. The power curves on full and three-quarter load are given in Fig. 15. The exhaust temperature curve is reproduced in Fig. 17, and the fuel consumption on a base of b.m.e.p. in shown in Fig. 18. The readings were taken with the engine running at 1,000 r.p.m., the fuel oil having a specific gravity of 0·843 at 15 deg. C.

THE NEWCOMEN SOCIETY.

At a meeting of the Newcomen Society, held on February 14, at the Iron and Steel Institute, under the chairmanship of Dr. C. H. Desch, F.R.S., two papers were read. The first, by Mr. H. H. Coghlan, was entitled "Prehistoric Copper and Some Experiments in Smelting." Native copper, said Mr. Coghlan, occurred as a mineral having the properties of the smelted metal. It was found in the form of thin plates and arborescent growths, or in a massive form in crevices in rocks. It was usually of a dark purplish colour, but, if scratched, was a yellowish red; so that it must have attracted the eye of prehistoric man. Originally, it was used for making small tools, ornaments, beads, etc. In its massive form it was very intractable to work. Microscopic examination had been made of prehistoric copper articles and it was possible to distinguish between hammered native copper and copper which had been smelted. In dealing with the chronology of early metals, it was important to know whether melting preceded smelting. Some held that the melting of native copper came before the smelting of copper from its ores, but Mr. Coghlan found it difficult to accept this view because of the difficulty of producing the high temperature required. He inclined to the opinion that the sequence of the first uses of copper was: (1) At some very early date, possibly 5000 B.C., small objects, such as beads, awls, etc., were hammered out of small pieces of native metal; (2) when the process of tempering copper was discovered and understood, larger and more complicated objects were made by hammering and tempering the native copper; (3) the discovery of the way to smelt copper from oxidised surface ores was made; (4) furnace technique and metallurgy had advanced sufficiently to smelt copper. Smelted copper was melted and cast, and, at the same time, native copper was melted and cast. The theory usually accepted of the discovery of smelting seemed to be that it was made accidentially in the camp fire or shepherd's fire, and it was to test this theory that Mr. Coghlan made his experiments. He endeavoured to reproduce the conditions likely to have been obtained in very early days, but his results were all negative. He thought, however, that it was possible for copper ore to have been smelted accidentally, in small quantities, in pottery kilns, and in an experiment reproducing the conditions in a kiln he did obtain compact and close-grained beads of copper from malachite, ground to a small size.

The second paper was a note on part of a diary kept by James Brindley, the canal engineer, and was contributed by Mr. A. Titley. The manuscript consisted of twenty pages of rough notes, made during 1755 and 1758, two pages of a diary written in 1761-2, and a copy of a letter from Brindley to Wedgwood. The entries related to corn mills, flint mills, silk mills, the atmospheric engine built by Brindley for John Broad of Fenton Vivian near Stoke-on-Trent, and a visit to London, when Brindley appeared before Parliament as a witness for the Duke of Bridgewater, when the Bill for the canal from Manchester to the Mersey was under consideration. Smiles had stated, said Mr. Titley, that the atmospheric engine built by Brindley had a cylinder of wood, but there was evidence in the manuscripts to dispose of this assertion; and it was known, from the ledgers of the Coalbrookdale Company, that, in 1756, the firm supplied a cylinder 60 in. in diameter and having a piston stroke of 10 ft., for Mr. Broad's engine.

The United States Colliery Industry.—The average daily output of bituminous coal in the United States during the week ending January 27, was 1,728,000 tons, against 1,653,000 tons in the previous week.

Fuel in Science and Practice.—The first number of the well-known journal of the scientific and economic use of fuels, which bears the title *Fuel in Science and Practice*, was published in 1922 and, as stated in a foreword by Sir Harold Hartley in the current issue of the Journal, it was founded to give wider publicity to the subjects of the informal discussions of the Coal Research Club, which had been established in 1921. The periodical was first published as a supplement to *The Colliery Guardian*, but its immediate success, which was mainly due to the labours of the original co-editors, Professor R. V. Wheeler and Dr. J. V. Elsden, soon justified its publication as an independent journal. It is published by Messrs. Fuel Publications, Limited, 30 and 31, Furnival-street, Holborn, E.C.4. For 18 years Professor Wheeler continued to take the principal part in guiding its destinies, but following his recent death the journal has entered a new phase. While retaining its independent character, it has now become, in addition, the research ournal of the Institute of Fuel. Dr. R. Lessing, who has been associated with Professor Wheeler from the inception of the journal, has taken over the editorship.

ENGINEERING TRAINING AND EDUCATION.

Research Scholarship in Application of Light Alloys to Ship Construction.—A research scholarship of the value of 250*l.* per annum and tenable for two years has been founded by the Wrought Light Alloys Development Association to encourage and facilitate research in the application of light alloys to ship construction. The scholarship will be administered by a committee of the Institution of Naval Architects and it is hoped to make the first award in September, 1940. Full particulars of entry, which closes on July 31, can be obtained from the Secretary of the Institution of Naval Architects, 10, Upper Belgrave-street, London, S.W.1.

North of England Institute of Mining and Mechanical Engineers.—The examinations for certificated studentships in mining and mechanical engineering, organised by the North of England Institute of Mining and Mechanical Engineers, will be held on Thursday, April 18. It is pointed out that at the present time there are no statutory examinations for mechanical engineers or for the grade of overman in mining, and the Institute examinations for certificated studentships are intended to be the equivalent of such examinations. While the main object of the Institute is to assist the training and development of young men for the mining industry, there is no age limit for applicants. Furthermore, there is no entrance fee and the examinations are open to all suitable applicants, whether they be members of the Institute or not. Success in the examinations, however, may entitle the applicant to an award in the form of the remission of future subscriptions to the Institute to the extent of 6*l.* 6*s.* Pamphlets have been prepared containing detailed particulars regarding the objects of the examinations, the rules to be observed, and instructions and advice to candidates, and these, together with application forms, may be obtained from the honorary secretary, Institute Board of Examinations, Neville Hall, Newcastle-upon-Tyne, 1.

TENDERS.

We have received from the Department of Overseas Trade, Great George-street, London, S.W.1, particulars of the undermentioned tenders, the closing dates of which are as stated. Details may be obtained on application to the Department at the above address, quoting the reference numbers given.

Telephone Cable. Post and Telegraph Department, Wellington, N.Z.; April 1. (T. 16,065/40.)

Transformer Bank, 3,000 kVA, for Wairoa substation. Palmerston North District. Public Works Supplies and Tenders Committee, Wellington, N.Z.; April 9. (T. 16,066/40.)

Switchgear, 11 kV. Public Works Supplies and Tenders Committee, Wellington, N.Z.; April 2. (T. 16,067/40.)

Control and Relay Panels for Mount Roskill substation, Auckland; May 21. (T. 16,068/40.) Similar equipment for Contract No. 650; May 21. (T. 16,069/40.); and for Contract No. 651; May 14. (T. 16,070/40.) Public Works Supplies and Tenders Committee, Wellington, N.Z.

Bar Steel. South African Railways and Harbours, Johannesburg; April 1. (T. 16,082/40.)

Structural Steel for Bridgework. Contract No. 2,557; April 8. (T. 16,086/40.) Similar material for Contract No. 2,559; April 4. (T. 16,088/40.) South African Railways and Harbours, Johannesburg.

Electric Cable, paper and varnished-cambric insulated. State Electricity Commission of Victoria, Melbourne, Australia; June 11. (T. 16,144/40.)

Machine Tools for H.M.I.N. Dockyard, Bombay. Indian Stores Department, Mechanical Section, New Delhi; March 14. (T. 16,186/40.)

Steaming Ovens for Fort Beaufort Mental Hospital. Union Tender and Supplies Board, Pretoria; March 14. (T. 16,296/40.)

Steam Tug. With reference to the call for tenders for a twin-screw steam tug, noted on page 62, *ante*, we now learn that the Ports and Lighthouses Administration, Alexandria, Egypt, has postponed the closing date until March 25. (T. 15,038/40.)

The Emergency Portable Gas Producer: Errata.—We regret that, owing to a misprint in our leading article on the emergency portable gas producer, on page 173 *ante*, it was stated that, in the H.S.G. producer, arrangements are provided for "receiving any clinker formed" without interfering with the operation of the producer. This should have read "for removing any clinker formed." A further misprint occurred near the top of the following page, where producers of the cross-draught type were referred to as cross-diagonal producers.

PERSONAL.

The Hon. R. H. Vivian Smith has been appointed a director of Messrs. Vickers Limited, Vickers House, Broadway, Westminster, London, S.W.1.

The office of Mr. Arno Penkuhn, who, as stated on page 170, *ante*, has acquired the sole manufacturing and sales rights of Artus milling-cutter spacers for Great Britain and the British Empire except Canada, is at 5, Avenue-gardens, London, W.3.

Mr. J. M. R. Fairbairn, who retired some time ago from the position of Chief Engineer to the Canadian Pacific Railway, has been elected an honorary member of the American Society of Civil Engineers.

Dr. A. L. Norbury has relinquished his position as senior metallurgist to the British Cast Iron Research Association, 21-23, St. Paul's-square, Birmingham, 3, to take up an appointment at the Research Department, Woolwich, London, S.E.18.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

Middlesbrough, Wednesday.

General Situation.—All sections of the market are steady and firm, and heavy tonnages of iron and steel are now moving into consumption. Both home and export inquiries circulating are on a large scale. The demand for commodities for the usual industrial requirements is considerable, and general commercial business is expanding, as tonnage becomes available for disposal, after the Government demands have been met.

Cleveland Iron Trade.—There is still no prospect of a resumption of the regular make of Cleveland pig, the supply of which is now very meagre. The intermittent output of a substitute iron is small, and is taken up by founders as it becomes available, but the main supply of foundry iron is from the Midlands. North of England consumers report that deliveries are regular and adequate. Second-hands possess practically no local iron, and the merchant business in brands from elsewhere is not extensive. The prices named for Continental makes are still too high to tempt founders to return to the use of foreign products. The fixed market values of Cleveland pig are ruled by No. 3 quality at 111*s.*, delivered within the Tees-side zone.

Hematite.—Conditions in the East Coast hematite branch are little changed. Makers are maintaining outputs at a high level, but their delivery obligations are heavy and stocks have fallen. The current needs of producers' own consuming works continue to absorb most of the supply, but the demands of buyers are unusually heavy and resources are being extended to satisfy the requirements of customers to whom licences have been issued. Users dependent on the market for iron have extensive running contracts, but are anxious to negotiate for further supplies. Producers, however, are disinclined to discuss new business, and market transactions are confined to a few small parcels. Merchants have command of only moderate quantities. The stabilised quotations are at the equivalent of No. 1 grade of hematite at 127*s.* 6*d.*, delivered to North of England areas.

Basic Iron.—Basic-iron makers' adjoining steel works continue to consume the whole of the output of the Tees-side furnaces, and with no iron for sale, the quotation of 104*s.* 6*d.* is nominal.

Foreign Ore.—The situation regarding foreign ore is satisfactory. Consumers have a fair amount of tonnage on hand, and imports are up to expectations.

Blast-Furnace Coke.—Holders of Durham blast-furnace coke are well sold and are not desirous of entering into further commitments at the current values. Under such conditions, there is little incentive to market negotiation. The recognised prices are based on good medium qualities at 31*s.* 8*d.*, at the ovens.

Manufactured Iron and Steel.—Semi-finished and finished iron and steel firms are busily employed. Imports of Continental semies, together with further increases in the home makes, are sufficient to meet the requirements of the re-rolling mills. Finished-iron firms have very substantial contracts to execute, and producers of finished steel are not only sold as extensively as they care to commit themselves, but, though operating their plant at full capacity, are experiencing difficulty in coping with demands. Pressure for larger deliveries of shipbuilding requisites is insistent, and all descriptions of heavy steel are promptly taken up as they become available.

Mineral Production in Quebec.—Statistics issued by the Bureau of Mines in Quebec show that 364,010 tons of asbestos, 953,151 oz. of gold, 1,162,042 oz. of silver, and 3,026,709 barrels of cement were produced in the Province during 1939. The totals for 1938 were 289,793 tons of asbestos, 876,628 oz. of gold, 1,188,908 oz. of silver, and 2,730,320 barrels of cement.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—There has been little change in the state of the Scottish steel trade since the last report, and the output is being maintained on a high level. The tonnage of steel at present being delivered to the shipyards is exceptionally large. That the steel workers are doing their share is proved by the fact that new record production figures are being obtained. The demands from the munition works are increasing steadily and everything possible is being done to maintain the full output. There is a steady demand for black and galvanised sheets. The following are the current quotations:—Boiler plates, 13*l.* 8*s.* per ton; ship plates, 12*l.* 10*s.* 6*d.* per ton; sections, 12*l.* 8*s.* per ton; medium plates (under $\frac{3}{16}$ in. thick), weighing 6 lb. or more, per square foot, 14*l.* per ton, and weighing under 6 lb. but not less than 4·81 lb. per square foot, 14*l.* 10*s.* per ton; black-steel sheets, No. 24 gauge, in not less than 4-ton lots, 17*l.* 10*s.* per ton; and galvanised corrugated sheets, No. 24 gauge, in not less than 4-ton lots, 20*l.* per ton.

Malleable-Iron Trade.—In the West of Scotland malleable-iron trade, a steady business is passing, and makers, having many good contracts on hand, are fully occupied. The demand for re-rolled steel bars is still strong, and although production is on a large scale, buyers are maintaining a constant pressure for deliveries. A large tonnage of semies is necessary to keep plant running, and the local supply is being augmented by shipments from the Continent. The current prices are as follows:—Crown bars, 12*l.* 17*s.* 6*d.* per ton; No. 3 bars, 12*l.* 10*s.* per ton, and No. 4 bars, 12*l.* 15*s.* per ton; and re-rolled steel bars (tested), in 4-ton lots, 14*l.* 3*s.* per ton, all for home delivery.

Scottish Pig-Iron Trade.—The past week has shown no slackening in the demand for Scottish pig-iron, and the trade as a whole is as busy as it has ever been. The blast furnaces are turning out a large tonnage, which is going rapidly into consumption and the steel makers are still pressing for deliveries. To-day's market prices are as follows:—Hematite, 6*l.* 7*s.* 6*d.* per ton, and basic iron, 5*l.* 4*s.* 6*d.* per ton, both delivered at the steelworks; foundry iron, No. 1, 5*l.* 15*s.* per ton, and No. 3, 5*l.* 12*s.* 6*d.* per ton, both on trucks at makers' yards.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Welsh Coal Trade.—Some large-scale business is expected to be placed shortly with local shippers by buyers in the Italian trade. During the past week the head of the Italian State Railways office in London visited Cardiff and interviewed the leading exporters and colliery interests regarding supplies of coal. Italy has been displaying a keen interest in the local market for some time past and it has been estimated that, since the outbreak of the war, she has bought about 4,000,000 tons from the United Kingdom for delivery over the twelve months. During recent years Germany has supplied the bulk of Italy's coal requirements, but the outbreak of war has enabled local exporters to recover a good deal of the business that was lost during the time that the imposition of sanctions against Italy brought business to a standstill. Interest was also aroused on the market by reports that a British delegation had visited Madrid and the Spanish officials had now reached agreement on all points regarding a new trade pact between the two countries. Recently, it will be remembered, a coal delegation from this country visited Spain in connection with the negotiations that have been proceeding for the new pact. At one time Spain took very large quantities of Welsh coals, but shipments have ceased since the conclusion of the Spanish civil war, except for a few odd cargoes. Demand remained brisk, on both home and export account, on the steam-coal market throughout the week. Supplies of coal, however, were still scarce, and the amount of new business that could be concluded was, consequently, reduced. Most collieries held sufficient orders on their books to absorb almost the whole of their potential outputs for some months to come, and the general tone was, therefore, very firm. Duff coals remained extremely scarce, while sized and large qualities were only very quietly offering and were firm; smalls were limited. Cokes came in for a good demand but were scarce; patent fuel was also in good demand.

The Iron and Steel Trade.—Active conditions were again in evidence in the iron and steel and allied trades of South Wales and Monmouthshire. The demand for finished products was maintained and works were engaged almost to capacity in fulfilling orders already on their books.

EXPORT LICENCES FOR TIN.—The Board of Trade has made an Order adding tin to the metals, which, with their alloys, in unwrought forms, require licences for export to any destination. The Order came into force on February 4.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—While Government requirements in steel and engineering products generally continue to show an increase, business in ordinary commercial products is also expanding. The export position is more satisfactory. Industrialists are keeping a special watch on foreign markets, and sales are being pushed in those areas which at one time relied chiefly on Germany for supplies; particular attention is being paid to South America. The inquiries received by the Sheffield Chamber of Commerce include: from London, for plasterers' trowels, knives and plates for mincing machines, and eyebolts; from France, for circular knives for rubber-thread cutting machines; from Turkey, for steel shafts; from Canada, for farm and garden tools; from Cyprus, for files, tools and steel; and from South Africa, for farming implements. The heavy machinery and engineering branches are accounting for record outputs. Rolling mills, forges, press shops, and billet mills are working at high pressure. Strip and bar mills report an accumulation of orders, and the recent active demand for steelworks and ironworks machinery shows no signs of slackening. Rolling mills and hydraulic presses are on order for industrial areas in other parts of the country. Business in railway rolling stock is more active, while shipbuilding requirements have been maintained at a high level. Power-station extensions are producing orders for hollow forgings and boiler drums; some of these are of record weight and size. In addition, there is a heavy demand for steel used in the production of transformers, generators, and other large-scale plant. Makers of textile machinery report that they are experiencing a rush of orders, and have had to introduce night shifts. Exports are on the increase, chiefly to Denmark, New Zealand, and the East Indies. Owing to the shortage of pit timber, a better demand is developing for steel props, arches, and girders. Good business is reported in concrete- and cement-mixing machinery, grinding and crushing machines, lime hydrators, rotary dryers, dust-collecting plant, and coal-crushing machines.

South Yorkshire Coal Trade.—Coal is moving more freely. Industrial concerns are beginning to build up stocks which have been depleted as a result of the unsatisfactory deliveries of recent weeks. Small coal is in demand by power stations and steam coal is a progressive section. The house coal market is also active. Most classes of coke are in good demand.

LAUNCH OF ITALIAN SUBMARINE.—The Italian ocean-going submarine Luigi-Torelli was launched recently at La Spezia. The vessel constitutes a unit of a series of 16 ships authorised under the 1938 budget. These vessels are to have a tonnage at least equal to that of eight other ships placed in commission between 1928 and 1935, namely, surface displacement 1,300 tons, and submerged displacement 1,800 to 1,900 tons. The armament will comprise two 4·7-in. guns and at least eight 21-in. torpedo tubes.

THE BENEVOLENT FUND OF THE INSTITUTION OF ELECTRICAL ENGINEERS.—The Electrical Engineers' Ball, which is usually held in February, has this year inevitably had to be cancelled, thus causing a loss of revenue of between 200*l.* and 250*l.* to the Benevolent Fund of the Institution of Electrical Engineers. At the same time, the demands on the Fund have increased since the outbreak of the war. The committee would, therefore, be grateful if those who normally attend the Ball would send a substantial donation to the Benevolent Fund instead.

THE LICENSING OF IMPORTED MACHINERY, PLANT AND APPLIANCES.—Cases have come to the notice of the Import Licensing Department in which importers have placed orders for machinery, plant and appliances, to be constructed abroad, without first ascertaining that a licence for the importation of the goods will be issued. Importers are accordingly warned that no goods of this class can now be imported without a licence unless they are consigned direct to a Government Department. It is emphasised that the fact that an order has already been placed will not influence the Department in the direction of granting a licence which it would otherwise refuse. Accordingly, importers are advised not to place any orders abroad for machinery, plant or appliances until they have either obtained an import licence or ascertained definitely that a licence will be granted, or that no licence is required. Where it is expected that some considerable time will elapse between the placing of the order and the delivery of the goods, arrangements can be made, if necessary, to extend the period of validity of any licence that may be issued beyond the usual period of three months. Further particulars may be obtained from the Import Licensing Department, Board of Trade, 25, Southampton Buildings, Chancery-lane, London, W.C.2.

NOTICES OF MEETINGS.

IT is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

JUNIOR INSTITUTION OF ENGINEERS.—To-night, 6.30 p.m., 39, Victoria-street, Westminster, S.W.1. Informal Meeting. Lecture: "The Application of Steam Propulsion to Road Vehicles," by Mr. M. H. Lewis. *Sheffield Section:* Friday, March 1, 7.30 p.m., Sheffield Metallurgical Club, West-street, Sheffield. Presidential Address: "Mechanical Properties in Relation to Design," by Professor H. W. Swift.

MANCHESTER ASSOCIATION OF ENGINEERS.—To-night, 7.15 p.m., Engineers' Club, Manchester. "Development in Design of Boilers and Boiler House Auxiliaries," by Mr. A. Pollitt.

INSTITUTION OF PRODUCTION ENGINEERS.—*Yorkshire Section:* Saturday, February 24, 2.30 p.m., Hotel Metropole, Leeds. Lecture: "Some New Applications of Optics to Engineering," by Mr. M. H. Taylor.

INSTITUTE OF BRITISH FOUNDRYMEN.—*Scottish Branch, Falkirk Section:* Saturday, February 24, 6 p.m., The Temperance Café, Lint Riggs, Falkirk. "Notes on the Production of Engineering Castings," by Mr. A. Marshall. Also at the *Lancashire Branch:* Saturday, March 2, 3 p.m., The Engineers' Club, Manchester.

INSTITUTION OF ELECTRICAL ENGINEERS.—Monday, February 26, 6 p.m., Savoy-place, Victoria-embankment, W.C.2. Informal Meeting. Discussion on "The I.E.E. Wiring Regulations, Eleventh Edition," to be opened by Mr. H. J. Cash. *South Midland Centre:* Monday, February 26, 6 p.m., The James Watt Memorial Institute, Birmingham. "The High-Rupturing Capacity Cartridge Fuse," by Mr. J. W. Gibson. *North-Eastern Centre:* Monday, February 26, 6.15 p.m., Newe House, Pilgrim-street, Newcastle-upon-Tyne. "Insulation Stresses in Transformers," by Mr. H. L. Thomas. *Scottish Centre:* Tuesday, February 27, 6.30 p.m., Royal Technical College, George-street, Glasgow, C.1. Discussion: "Operation of the Grid System," to be opened by Mr. A. E. McColl. *West Wales (Swansea) Sub-Centre:* Thursday, February 29, 6.30 p.m., Technical College, Mount Pleasant, Swansea. "Legal and Technical Implications of the Electricity Supply (Meters) Act, 1936," by Mr. Alwyn Evans.

INSTITUTION OF MECHANICAL ENGINEERS.—*Scottish Graduates' Section:* Monday, February 26, 7.15 p.m., Royal Technical College, George-street, Glasgow, C.1. "German Production Methods," by Dr.-Ing. H. Orenstein. *Steam Group:* Friday, March 1, 6 p.m., Storey's-gate, Westminster, S.W.1. Extra General Meeting. "Circulation of Water and Steam in Water-Tube Boilers, and the Rational Simplification of Boiler Design," by Messrs. W. Y. Lewis and S. A. Robertson.

ROYAL INSTITUTION.—Tuesday, February 27, 3 p.m., 21, Albemarle-street, W.1. "The Present-Day Study of the Stars," by Professor Sir James Jeans. Wednesday, February 28, 5.15 p.m., "X-Ray Optics," by Professor W. L. Bragg.

SOCIETY OF CHEMICAL INDUSTRY.—Tuesday, February 27, 6 p.m., The University, Western Bank, Sheffield. Jubilee Memorial Lecture: "Recent Advances in the Applied Chemistry of the Rarer Metals," by Mr. R. H. Atkinson.

ROYAL SOCIETY OF ARTS.—Wednesday, February 28, 2.30 p.m., John Adam-street, W.C.2. "Alternative Motor Fuels," by Dr. C. M. Walter.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—*Student Section:* Wednesday, February 28, 6.45 p.m., Bolbec Hall, Newcastle-upon-Tyne, 1. "Rudder Design," by Mr. L. A. Oliver.

INSTITUTE OF FUEL.—Thursday, February 29, 6 p.m., Neville Hall, Newcastle-on-Tyne. "Modern Gas Storage," by Mr. Stanley Thomson.

THE HERBERT JACKSON PRIZE.—The London Midland and Scottish Railway Company has announced that the Herbert Jackson Prize for 1939 has been awarded to Mr. H. I. Andrews, Engineering Section, Research Department, Derby, for his paper entitled, "The Development of a Refrigerating Machine for Use on Trains."

TRIALS OF MOTOR TORPEDO BOATS.—Messrs. John I. Thornycroft and Company, Limited, Thornycroft House, Smith-square, London, S.W.1, inform us that motor torpedo boats, recently completed by them for a foreign Government, have attained a speed of over 48 knots when carrying full war load. The vessels, which are 55 ft. in length, are each fitted with two Thornycroft 12-cylinder petrol marine engines of a total horse-power of 1,300.

NON-OSCILLATING PETERSEN COIL.

CONSTRUCTED BY THE OERLIKON COMPANY, LIMITED, OERLIKON, SWITZERLAND.

(*For Description, see Page* 194.)

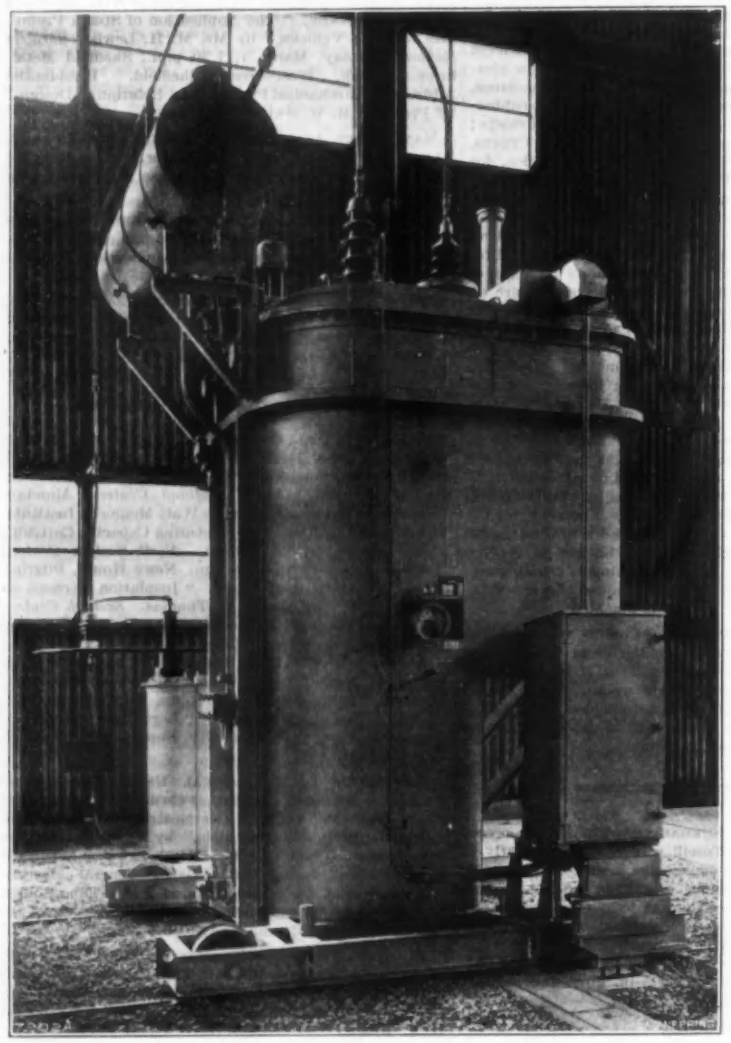


Fig. 1. 5,650-KVA Arc-Suppression Coil for 150-KV System.

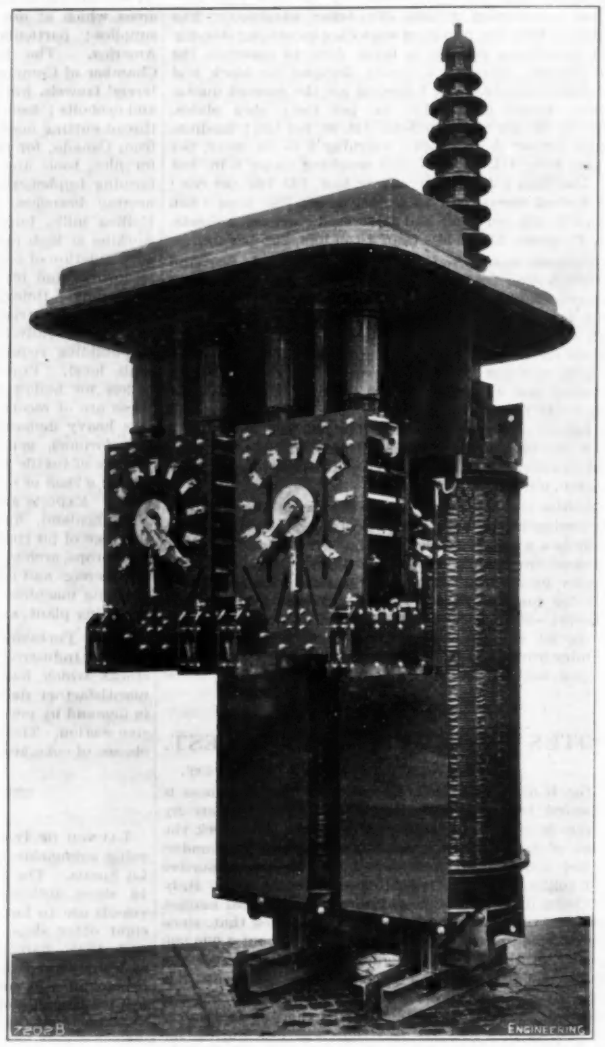


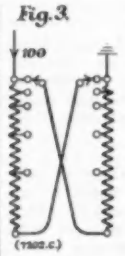
Fig. 2. Coil with Cover Removed.

FUEL RESEARCH AT THE UNIVERSITY OF LEEDS.

Ever since its establishment in 1906, the Department of Coal Gas and Fuel Industries with Metallurgy of the University of Leeds has been closely connected with industrial research, and, from 1929 onwards, the Joint Research Committee of the Institution of Gas Engineers and the University has been responsible for much important work. An excellent impression of the research achievements of the Department is conveyed by the fact that, since its inception until 1938, as many as 180 contributions to scientific literature were published, comprising 73 committee reports, 104 scientific papers and 3 monographs. A report on the work accomplished during each academic year is issued annually by the Livesey Professor, who is in charge of the Department, and that for the 1938-39 session, which has recently come to hand, constitutes the first to have been prepared by Professor D. T. A. Townend, who succeeded Professor J. W. Cobb in the Livesey Chair during the session. The report states that the extensive investigations of the Joint Research Committee have been actively pursued and that the 45th and 46th reports have been drafted. The first of these contains a comprehensive account of the possibilities of high-pressure gasification as a source of town-gas supply. The 46th report deals more particularly with a study of the mechanisms of the reactions, with carbon, of carbon dioxide and steam. In the public interest these two reports are not being published at the present time.

It may be recalled that the Alloy Steels Joint Research Committee of the Iron and Steel Institute and the British Iron and Steel Federation entrusted to the Department work on the examination of oxide-scale formation on special steels in furnace atmospheres. A second report on this research was presented before the Iron and Steel Institute in May, 1939, and in spite of difficulties created by the war, the Alloy Steels Committee has decided to continue to support the work for a further period of three years. The research is, therefore, being extended, under the direction of Mr. A. Preece, to higher furnace temperatures and to more complex types of steel. A feature of the work of the Department, which is becoming of increasing importance, is the facility it provides for industrial research students. These young men are employed by private concerns and come to the University to investigate specific problems under the supervision of a member of the staff. Such an arrangement, it is pointed out, offers advantages to all parties.

Fig.3.



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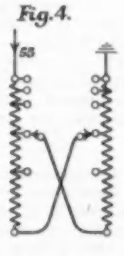

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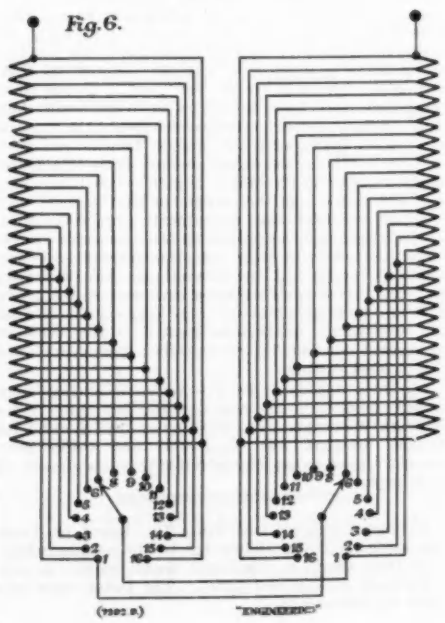
Fig.6.



PROTOTYPE ENGINES OPERATING ON THE KADENACY SYSTEM.

MESSRS. ARMSTRONG WHITWORTH SECURITIES COMPANY, LIMITED, ENGINEERS, SLOUGH.

(*For Description, see Page* 195.)

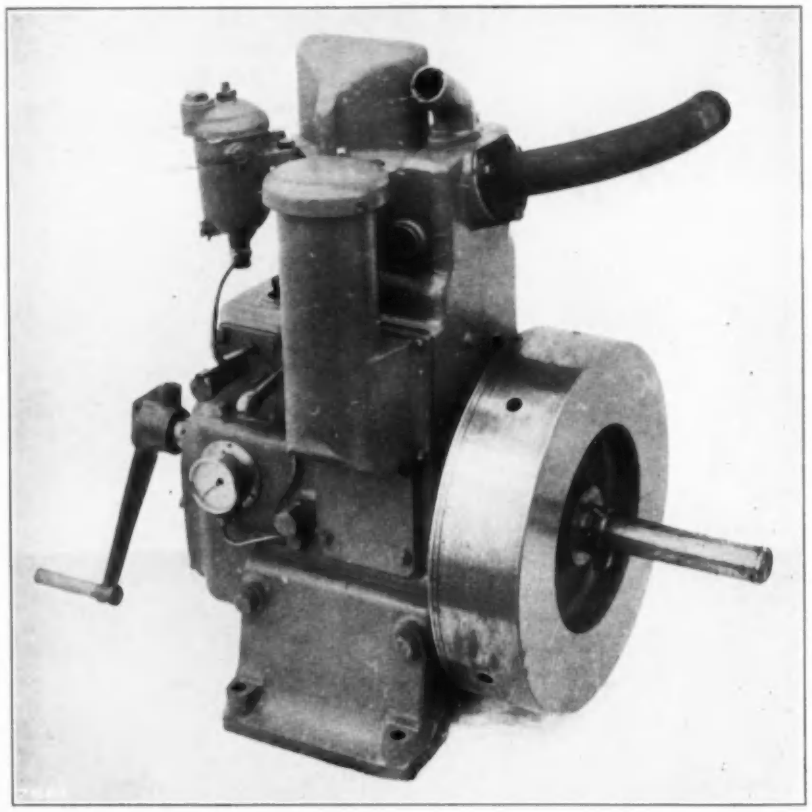


FIG. 1. SINGLE-CYLINDER INDUSTRIAL ENGINE.

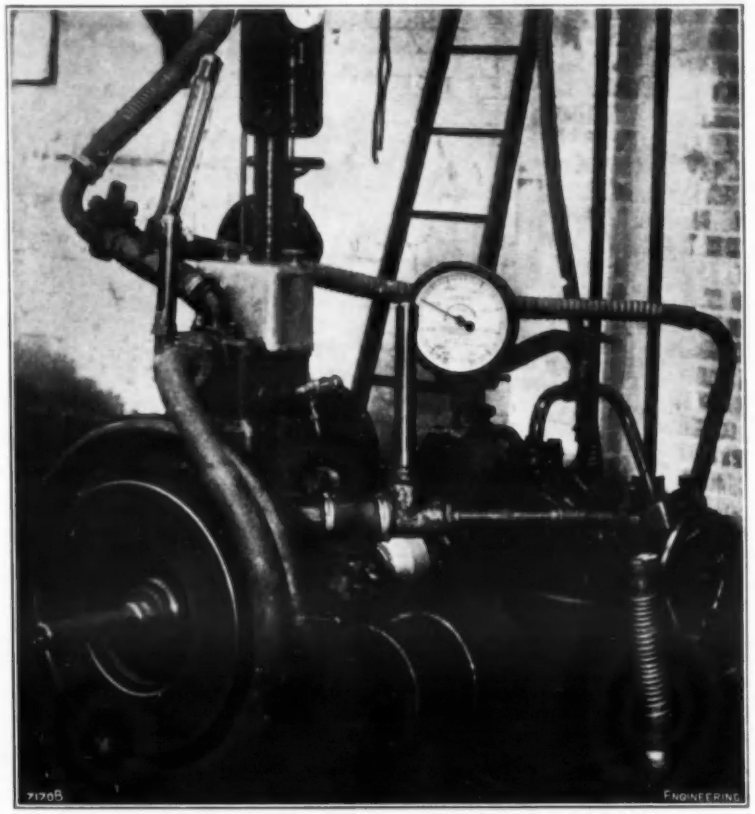
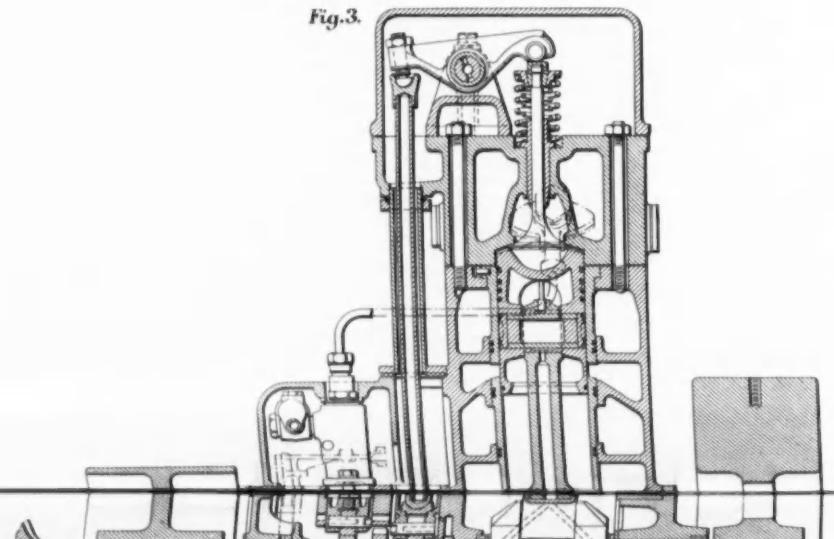


FIG. 2. SINGLE-CYLINDER ENGINE ARRANGED FOR TESTING.

Fig.3.



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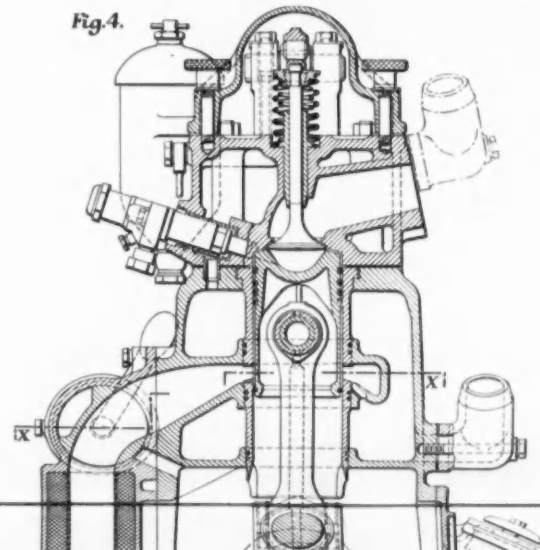

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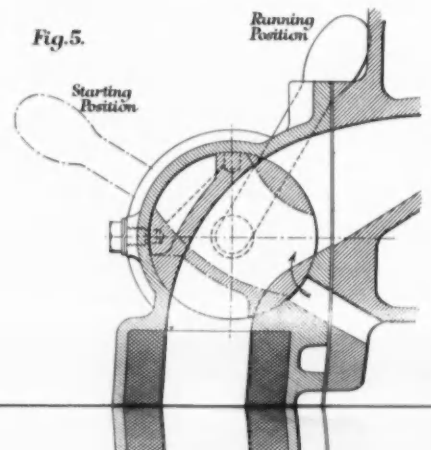


UNIV. OF MICH.

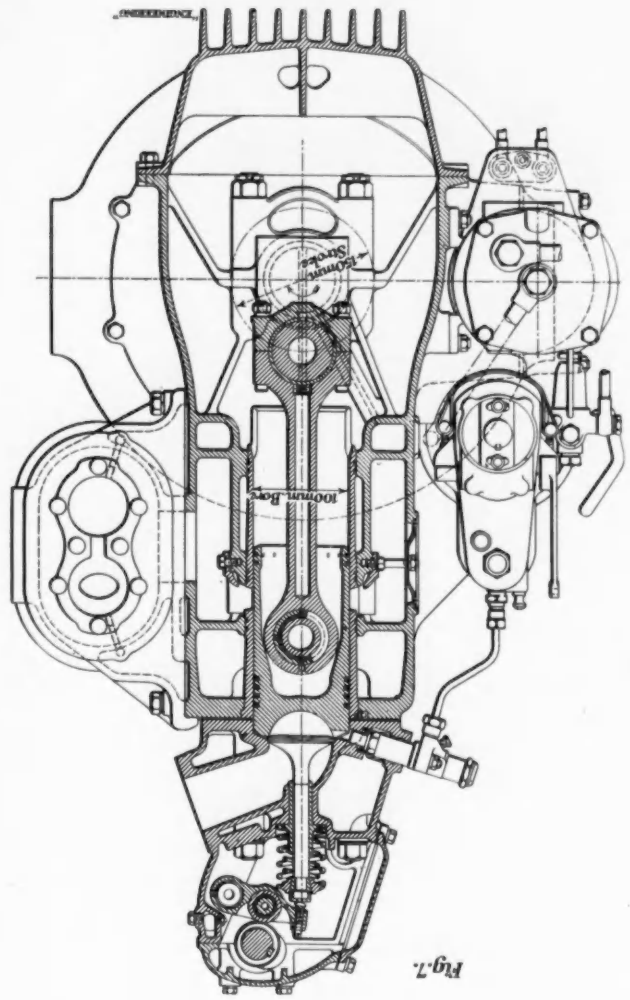
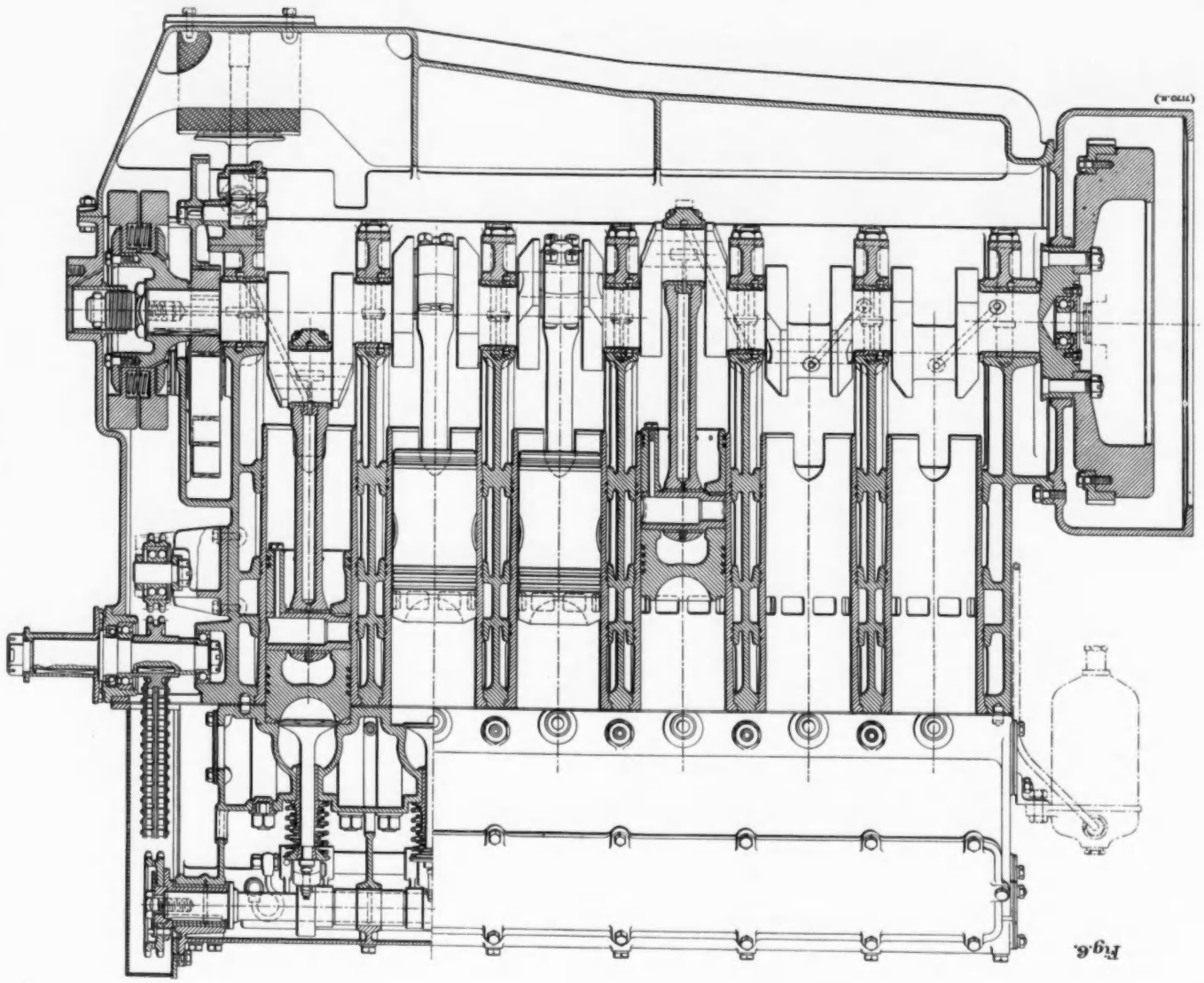


Fig.7.



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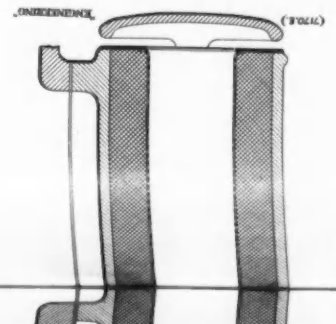

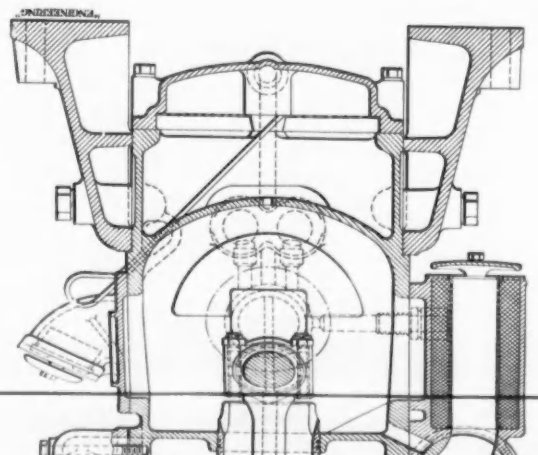

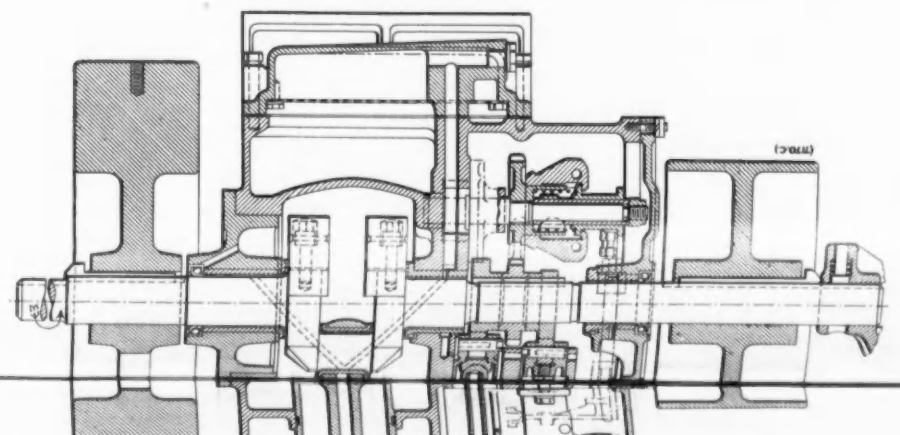

ENGINEERING.

Offices for Publication and Advertisements, 35 & 36, Bedford Street, Strand, London, W.C.2.

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TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be delivered not later than first post on Wednesday. Alterations to standing advertisements must be received at least 10 days previous to the day of Publication. Passed proofs must be in our hands by Saturday morning, otherwise they will be taken as correct. The proprietors will not hold themselves responsible for blocks left in their possession for more than two years.

All accounts are payable to "ENGINEERING," Ltd. Cheques should be crossed "The National Provincial Bank, Limited, Charing Cross Branch." Post Office Orders should be made payable at Bedford Street, Strand, W.C.2.

TEMPORARY ADDRESS.

For the duration of hostilities, the Editorial and Publishing business of this Journal is being conducted from 18 and 20, Compton Road, Hayes, Middlesex. The Telephone Number of the Editorial Department is Hayes 1730, and that of the Publishing Department, Hayes 1723. The Bedford Street Offices are open on Fridays only, between 10 a.m. and 5 p.m., for the distribution of the current issue and for retail sales.

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ENGINEERING

FRIDAY, FEBRUARY 23, 1940.

VOL. 149. No. 3867.

THE RAILWAY SETTLEMENT.

AT the beginning of the war of 1914-18 the railways of Great Britain were taken over by the Government under the Regulation of Forces Act, 1871, though day-by-day control was exercised by an Executive Committee consisting of the general managers of the various companies. In principle there was no objection to this arrangement, for it is clear that during war time the operation of one of the principal methods of transport in the country must be subject to military exigencies and that shareholders, no less than ordinary users, must be required to forgo some of their usual rights. In detail, however, the scheme was not well conceived ; and especially when the railways came to be handed back to their owners in 1921, experience showed that improvements could be made. In the first place, the Government had guaranteed a net revenue to the companies, but made no payment for military and naval transport, thus unnecessarily confusing two items of expenditure in the national balance sheet. In the second place, there was a huge bill for "deferred maintenance" and depleted stores, which not only imposed a further burden on the country's finances, but left the railways with a considerable leeway of improvements to make up.

At the beginning of the present war the Government again took over the railways, and once more control is being exercised through an Executive Committee of managers. It was only last week, however, that the methods by which compensation is to be apportioned were decided. These indicate that some attempt has been made to overcome the drawbacks of the former arrangements. In the first place, the compensation payable will be governed, subject to guaranteed minima, by the actual net earnings of the companies, while the Government will share in any net earnings above a predetermined level. In the second place, the wise decision has been reached that payment should be made for the conveyance of Government traffic on a commercial basis, thus avoiding the confusion to which we have alluded. As the railways will continue to operate with the minimum of control and will have free use of the revenue they collect, no bill for deferred maintenance should be necessary on this occasion.

Naturally, the settlement is not without its complications in detail, but it may be briefly explained as follows :—The net revenue of the four main-line railways and of the London Passenger Transport Board will be pooled and out of it a minimum annual payment will be made to each of the constituents. This minimum will be equal to the net revenue of each of the railways for the average of the years 1935, 1936 and 1937, and the net revenue of the London Passenger Transport Board for the year ended June 30, 1939. It is estimated that it will total about 40,000,000*l.*; otherwise, it will be made up to that amount by the Government. If it exceeds 40,000,000*l.*, a further 3,500,000*l.* will be paid out to the five undertakings in the proportions of the minimum guarantee, while, if it exceeds 43,500,000*l.*, there will be an equal division of the excess between the Government on the one hand and the five undertakings on the other, until a limit of 68,500,000*l.* has been reached. The share of the five undertakings will be divided in the same proportions as before, but no company will be allowed to receive more than its standard revenue, nor the London Passenger Transport Board more than the standard rate on its "C" stock. The aggregate of these standard revenues is 56,000,000*l.*, and the limit is therefore twice the difference between this and 43,500,000*l.*, namely, 25,000,000*l.*, which makes up the 68,500,000*l.* just mentioned. These figures are subject to the qualifications that the charge to the pool for restoring war damage is limited to 10,000,000*l.* in any one year, and that a non-recurring payment of between 2,000,000*l.* and 3,000,000*l.* is to be made to the Exchequer for certain air-raid precaution work that has been financed by the Government. In this connection, it may be noted that the average net revenue of the companies in the "basic years" was only 33,700,000*l.*, so that, in fixing the guaranteed minimum at 41,000,000*l.*, the Government is risking a not inconsiderable sum. This may explain the rise in the price of stocks which has taken place, though it may be argued that even now the shareholders will not make a fortune.

The broad effect of the arrangements is, in fact, that the main-line companies are guaranteed a minimum return on their total capital of 3·3 per cent., and can look forward, perhaps not too optimistically, to a maximum return of 4·7 per cent. At the same time, they lose the benefit relating to the fixation of charges given by the Railways Act, 1921, and have to share their net revenues with the Government. On the other hand, they may find it easier to raise their charges if they wish. The railways themselves view the scheme as one which reduces their potential earnings, while providing a minimum return. From their point of view, therefore, it may not be altogether an advantage, since the diversion of the traffic from the roads might well result, in the near future, in a much greater standard of prosperity than has been reached in recent years. In part, of course, the attainment of this prosperity will depend on the use that is made of the railways by the Government, since the trade of the country is passing more and more into their hands. If it is attained, the fruits will have to be shared with the principal customer, which is certainly a novel principle, though equally certainly it is justified by the needs of the country in war time.

Moreover, it is as well to note that the existing machinery for adjusting charges is to be suspended and in its place a new method is to be adopted whereby adjustments will be made as necessary to meet variations in prices and conditions as compared with those existing immediately before the war. If the rises in prices of materials, and consequently charges, are kept within reasonable limits, no great difficulties will arise, but if they are not, there is

still a possibility that traffic may be diverted to the roads, notwithstanding petrol rationing. The Government, it may be recalled, will have to pay the railways' charges like any other user, and if these charges increase above a certain figure may itself find it economical to use the roads. It is true that, by so doing, it may have to implement its guarantee, but even if this happens it does not leave the railway shareholders in a particularly prosperous position. At any rate, the possibility imposes on the companies strong financial reasons for economical management, and may do something to check the temptation of employees to demand increased wages, which the intrusion of Government into private enterprise inevitably encourages.

THE GRADE OF ORE.

In pursuance of President Roosevelt's "New Deal" policy and the vigorous campaign against unemployment which characterised it, numerous investigations were carried out in the United States by an organisation created for the purpose and known as the Works Progress Administration. Reports published by the W.P.A. National Research Project are divided into the three main groups of mining, agriculture and manufacture. While some of these may be doomed to early oblivion by the march of events, and fundamental changes in conditions, this cannot be said of the report dealing with the grade of ore and its relation to output per man. This report* covers much of the history of metal mining in the United States, and will remain of permanent interest and value as an authoritative record of facts and a study of a problem which concerns metal mining in general, namely, the downward trend in the grade of ore. This problem has been made familiar by many papers read before the leading mining institutions and by technical articles and discussions, and is probably within the experience of most metal-mining engineers.

The economics of mining are complex at the best of times, owing to the many and variable factors which influence them. The fundamental law of supply and demand is affected in varying degree by such conditions as availability of ore, grade of ore and cost of working, which are to a great extent inter-dependent and are dependent also on other conditions, such as labour supply and wages. These and other factors may exhibit wide fluctuations when considered over a period of years.

In the early days of metal mining in the United States, the known reserves of gold, silver, copper, lead and zinc steadily increased as methods and knowledge improved, and the search for minerals became more intense. The enormous development of industry and commerce caused a rapid expansion of the demand for minerals of all kinds, and, the rich surface deposits being quickly exhausted, new methods were developed which enabled the larger low-grade deposits to be profitably exploited. The result was a decline in the average yield of metal per ton of ore worked. This tendency for the grade of ore to decline with increasing production is a characteristic feature of long-continued mining processes. Examples are seen in the long-time trends for each ore, the yield declining sharply at first and then sloping less steeply under the influence of controlled mining, in which the ore is extracted from the various workings in such manner that the resulting aggregate will give a desired yield. The rich portion of a mineral deposit is usually limited, and once this has been removed in the early days of working the mine, subsequent changes in the values are more gradual. There appears to be a characteristic range of grade for each stage of production, and it is significant that this range has been continuously lowered over a long period.

The relation between declining tenor and ore tonnage is not precise; it cannot be expressed as a simple methematical formula, because the descent of grade is not uniform. The rate of decline varies from time to time, and is greater in some kinds of ore than in others; it differs, too, in the several regions and districts. Hence movements of yield for the United States ores of any given sort represent composite trends and are made up of the variously moving regional trends of grade. It is exceptional to find an ore deposit which is uniform in tenor and consistent either in width or at a given depth. Most deposits tend to vary both in their values and in shape, and there are many instances of a lowering of grade accompanying vertical or horizontal extension of the workings.

Early records of mining show that, when the lodes were first worked, astonishingly high yields were often obtained from small tonnages of high-grade ore that could be mined by primitive methods using the simplest of tools and very little explosive. New ore bodies of comparable quality are no longer to be found; but, on the other hand, modern technology has made possible the exploitation of enormous bodies of ore very much lower in grade. The many influences that determine the grade of ore mined at a particular time illustrate the difficulty of separating the effect of technological developments from the effects of related geologic and economic factors. Of the three primary considerations in mineral production, the geologic factor is limited or fixed, whereas the others, the technical and economic factors, are variable. Technology, however, though always governed to some extent by the character of ore deposits, can be modified and improved, so changing the economic bearing of the geological limitation.

One of the significant aspects of technological progress was the change from small-scale to large-scale production. Primitive methods were replaced by more effective means, giving large haulage ways, roomier stopes, and, above all, larger quantities of ore in the chute. Improvements in haulage and equipment made possible more rapid transport of this material from chutes to skips. Buckets were enlarged; winding ropes were made of steel; steam power replaced horse whims, and later were followed by electric hoisting machinery. Such advances, combined with better knowledge of mining methods, overcame handicaps of depth and distance, increased the efficiency of operation, and permitted the mining of lower-grade ores. Even where ore values persisted more or less unchanged at depth in the primary ore bodies, technical changes promoted the utilisation of lower-grade ores by extending the limit at which metal-bearing rock could be profitably handled. Mass-mining methods also have facilitated the exploitation of low-grade ores. The benefit from technical progress, however, could not be applied entirely to reducing the grade of the ore, since some of the gains were absorbed by the changing physical nature of operations. In many instances, for example, large tonnages were made possible only by greatly extending the workings, which frequently involved both horizontal and vertical extension of the mine. Deepening resulted in numerous physical handicaps; heat, humidity and water tended to become more troublesome. Artificial ventilation had to be installed, water had to be pumped or drainage tunnels built.

One of the important factors which compensate for a declining grade of ore has been the technical progress that has effected a constantly greater proportionate recovery of the valuable content. As early as about 1780, Spanish metallurgists were recovering 50 per cent. of the metal content from the Mississippi Valley lead ores. This average was not bettered until the reverberatory smelter was introduced by Moses Austin in Missouri, about 1797. By 1820 recoveries of 62·5 per cent. were usual. Blast furnaces and, later, reverberatory furnaces were used for treating base ores. Lixiviation or leaching was adapted for the treatment of copper ores. An increasingly refined and more flexible smelter technique became available within the past generation, by the development of the Cottrell precipitator, and electrothermic and electrolytic processes. These made possible the treatment, and hence the mining, of increasingly complex ores of steadily declining grade.

This development of smelting was accompanied by comparable progress in the milling of ores. Gold was recovered at first in the arrastra and the Mexican patio; then plate amalgamation, chlorination, and cyaniding followed in due course, with notably improved recovery at each innovation. Advances in the design of crushing machinery, and in methods of sizing and classifying, contributed to the general progress. The introduction of selective flotation was of revolutionary importance, making practicable the mining of bodies of ore so low in grade, or so complex in mineralogy, that their exploitation was previously regarded as economically impossible. Changes in ore dressing and smelting also have made possible the lowering of the grade of ore that can be profitably worked and thus have enabled the mines to produce the larger tonnage required by the increasing demand for metals. Grade of ore should not be confused with yield, and the improved recovery technology which increased the yield partly masked the full extent of the drop that actually took place in the grade. Since yield is measured in terms of the metal recovered after the ore comes from the mill or smelter, it reflects the advances achieved in ore dressing and metallurgy, as well as the changes in the grade of the ore as mined. Statistics based on yield are liable to be misleading, therefore, if used as a measure of grade.

Other factors, not immediately connected with the ore body or the mining and milling process, affected the grade of the ore that could be mined; among these, the prevailing mode and cost of transport were of special importance. In the early days, transportation was mostly by mule, a method which was not only slow and costly, but limited the amount that could be transported, and thus, in practice, the output of the mines. The advent of railways brought about a vast change in conditions. As the railways were gradually extended and tapped the various mining camps, production on a larger scale became possible, local ore sellers were brought within reach of world markets, and complex ores could be shipped to distant smelters better equipped to deal with them. While reductions in transport costs lowered the effective grade, further stimulus came from another source. Small enterprises were consolidated; the area subject to costly litigation was reduced, and such properties benefited from large-scale management and engineering practice. This tendency to consolidation, reducing the number of small properties and greatly increasing the size of mining concerns, has exerted a powerful influence and is closely related with the development of technique for handling enormous quantities of materials at low cost.

The prospects for a continuance in the decline of ore grade turn on the question whether future metal supplies in the United States will come from present active districts, where the reserves of workable ore are fairly well known and the life of which would be prolonged by extending the workings into the outlying bodies of low-grade material, or whether the supplies will be drawn from new, higher-grade sources still to be discovered. The principal metal-mining districts of the United States were discovered relatively soon after the regions were occupied by the pioneers, and the possibility that new discoveries will be made to turn the grade upward with new rich "bonanzas" is not very encouraging. It is significant to note that no great finds have been made in the last quarter-century; and, of the 33 leading districts producing gold, silver, copper, lead, zinc, and even iron, only five have been found since 1900, and none at all since 1907. Small deposits, hitherto overlooked, may be discovered and the relatively new art of geophysical prospecting may perhaps prove useful in locating extensions of known ore bodies, and possibly, as the art is further developed, in finding new ore where no sign of its presence is at present detectable on the surface. In the main, however, the discovery of hitherto unknown rich deposits of high-grade ore, sufficient to meet an appreciable share of modern demand, is considered improbable. There would appear to be little escape from the prospect that future metal mining must adjust itself to a further lowering of ore grade. Greater efficiency in recovery will be purchased at a cost of greatly increased technological effort, because the margin for potential improvement has so considerably narrowed, but they must be achieved if lower-grade and more complex ores are to be utilised to meet the still rising demand for metals.

* *Mineral Technology and Output per Man Studies: Grade of Ore.* W.P.A. National Research Project and Department of the Interior and Bureau of Mines, Washington, D.C.

NOTES.

THE CONTROL OF PAPER.

SOME interesting statistics of the paper consumption in the United Kingdom, and an outline of the manner in which future supplies are to be controlled, were given at a Press conference on February 15 by Mr. A. Ralph Reed, Controller of Paper under the Ministry of Supply. The total consumption of paper and paper board during 1938, Mr. Reed stated, amounted to about 3¼ million tons, of which almost exactly one-third was imported. Newsprint, representing 1,241,000 tons, was the largest item in the total, and other printing papers accounted for an additional 364,000 tons. Wrapping papers totalled 605,000 tons, and boards 796,000 tons. The consumption of writing papers was 144,000 tons. The manufacture of the 2,300,000 tons of paper, etc., produced in the country required the importation of about 1,600,000 tons of wood pulp, 340,000 tons of pulp wood, and 311,000 tons of esparto grass. The greater part of these imports of paper-making materials are derived, in normal times, from Sweden, Norway and Finland, but a large amount of newsprint is obtained also from Canada and Newfoundland, and the esparto grass comes from North Africa. All of these routes being exposed to enemy attack, it was to be expected that the supplies from these sources would suffer appreciable diminution, and this factor was one of the first to be considered in organising the Paper Control. Another factor of importance was the growth of carton, paper-box and container manufacture, and that of building boards; and, of course, provision had to be made for a greatly increased demand by H.M. Stationery Office, to meet the war time needs of the fighting and civil services. Incidentally, it was found that not less than 8,000 factories depended on paper as their raw material for manufacturing processes. In the general interest of these various consumers, therefore, it was decided to fix maximum prices, at the outset, for all kinds of paper; these prices, which were fixed at the level obtaining immediately before the war, came into effect on September 2. The control extended to all paper-making materials, but increased freight costs caused a substantial rise in the cost of imported materials, and it was found necessary to issue, in October, a new schedule of prices, which is still in operation and represents an increase of from 20 per cent. to 50 per cent. over pre-war rates. Meanwhile, the demand for certain classes of paper had expanded enormously, as was expected; and, although, by voluntary action on the part of newspapers, the consumption of newsprint had been reduced to only 53 per cent. of the pre-war figure, the demand upon shipping space was sufficiently serious to make rationing desirable. Accordingly, a new Order had been made, limiting the quantity which might be supplied by any paper mill to a particular consumer to 60 per cent. of the quantity supplied in the corresponding period before the war, except under licence of the Ministry of Supply. The first rationing and licensing period would run from March 3 to May 31, after which a further Order would become operative. It would be the aim of the Ministry, Mr. Reed emphasised, to licence such extra quantities as might be required for purposes regarded as essential in the national interest; but he wished to stress particularly the necessity of avoiding waste of paper, or its consumption for non-essential purposes. The Salvage Department of the Ministry was saving waste paper already, to the extent of 50,000 tons per year, but it was felt that this quantity could be very greatly increased and a close liaison was being maintained with the Salvage Department with that intent.

SMALL FIRMS AND WAR CONTRACTS.

That the complaint that small firms were not receiving their fair share of war contracts has received the sympathetic consideration of the Government is shown by a letter which has recently been addressed by the Ministry of Supply to the Federation of British Industries. In this it is pointed out that one of the objects of the new area organisation, details of which have already been given in ENGINEERING, is to bring increasingly into production some of the available engineering capacity in establishment of this class. It is proposed, therefore, to examine the offers of capacity of all those firms who wish to be considered for munitions production through the medium of the area advisory committees and area boards that are to be set up. The Federation is also being asked to assist the Ministry by inviting its local officers to render what help they can in an advisory capacity to the secretaries of the area boards, who are the channels to the advisory committees for the reference of all offers of capacity. The Federation has expressed its willingness to give assistance in this or any other direction. It is to be hoped, therefore, that the full employment of this potential addition to the national war effort will not be long delayed.

MAINTAINING ELECTRICITY SUPPLY TO COLLIERIES.

Of the 237 coal mines in both districts of the Yorkshire coal field, 167 use electricity and of these, 60 per cent. take their supply from the mains of the Yorkshire Electric Power Company. Of the remainder, many have generating plant which is in excess of their requirements, and to ensure the maintenance of the supply during conditions which may arise in war, it has been decided, according to the *Electrical Review*, to interconnect this equipment with the power company's system. At the same time, a reinforcement of the company's supply for other vital war purposes will be secured. The interconnection will be made by the power company extending its mains to the individual colliery and fitting at some suitable place apparatus of a capacity sufficient for the amount of power to be interchanged or for such larger amount as the colliery may require. By these means, each party will endeavour at any time, when called upon to do so, to assist the other by the supply of electricity up to the amount of surplus power available within the capacity of the interconnecting apparatus, and the interchange of supply will be on equal terms. It may be noted that this is not the first example of co-operation between the Yorkshire collieries and the Yorkshire Electric Power Company. The latter have been using surplus coke-oven gas for twenty years for producing electricity, and, under joint working arrangements with various collieries, have utilised their surplus power.

THE OPERATION OF THE COAL MARKETING SCHEMES.

A report, which was issued by the Mines Department at the beginning of the week, deals with the operation of the coal marketing schemes and mentions that their introduction coincided with active conditions in the industry. It was, in fact, these conditions, rather than anything in the schemes themselves, which were responsible for the good results obtained during the first three years. During 1937, buyers did not foresee a point where a halt might be expected in the upward trend of prices and there was a tendency to buy well ahead of current needs. When the recession in industrial activity occurred in 1938, the contraction in the demand for coal was, therefore, disproportionately great. These conditions imposed a sudden and severe strain on the marketing system and it is certain that without statutory control prices would have fallen to low levels. Actually, though some reductions had to be made, the control bodies succeeded generally in maintaining prices on the internal market at the levels ruling at the beginning of the year. On the other hand, the average price realised at the pithead tended to be higher at the end of 1938 than twelve months previously, for many qualities of coal, the reason being that an appreciable proportion of the coal disposed of in 1937 was sold under pre-control contracts at low prices. Further steps were taken to bring about co-ordination between the coal-mining districts. For instance, it was made obligatory on districts to refer inter-district matters to co-ordinating committees, and final sanction, when necessary, was vested in the Central Council. Directions dealing with the rail-borne and coastwise trades were issued, the matter being particularly complex owing to the variations between rail and sea freights and the difficulty of arriving at shares of the trade acceptable to the various districts concerned. At the outset, the Central Council's directions applied only to the London area, but similar arrangements were issued in January, 1939, in respect of an area south of a line drawn from the Wash to the Bristol Channel. Finally, progress was made towards the co-ordination of the export trade, directions being issued fixing the relative tonnage shares of the districts interested. Minimum export price schedules were also prepared and consultation regarding tonnage, price and other conditions of sale was suggested, while steps were taken to establish effective control of these provisions. The outbreak of war, however, prevented this scheme being put into operation.

SIR HIRAM S. MAXIM (1840-1916).

On February 25, 1840, the famous inventor and engineer, Sir Hiram Stevens Maxim, was born at Sangerville, in Maine, "the best State in the Union to emigrate from." The story of his boyhood has many parallels in American biography. Though he enjoyed but little schooling, he had opportunities of learning and practising many handicrafts, and from the first displayed remarkable manual skill. Like his contemporary, Edison, he owed much to books. As a young man, during one winter he appears to have read through Ure's *Dictionary of Arts, Mines and Manufactures*, and in his autobiography, written a year before he died, he said, "I have always gone in very strongly for what is known as book learning." For him, indeed, books took the place of a technical college. His first notable success as an inventor was his improvement of the gas-making machine, an apparatus for producing lighting gas from gasoline. A company was formed to exploit the medium, and many plants were erected. From lighting by gas he turned to lighting by electricity, and, with Swan, Edison and Lane-Fox, is regarded as a pioneer of the incandescent lamp. He took out patents for lamps, dynamos, regulators and batteries. He also became engineer to the United States Electric Lighting Company, the first of its kind in the United States. In 1881, the company sent him to Europe to represent them at the Paris Exhibition. It was a chance conversation while on the Continent which caused him to invent the first fully-automatic machine-gun. The original gun was constructed in his workshop at 57D, Hatton-garden, London. While the gun was still in the embryo stage, Maxim was introduced to Albert Vickers (1838-1919), of Sheffield, who became the chairman of the Maxim Gun Company, formed in 1884. In 1885, Maxim described his gun to the Institution of Mechanical Engineers; in 1888, the Maxim Company was amalgamated with the Nordenfelt Company, under the name of the Maxim-Nordenfelt Guns and Ammunition Company, and, in 1889, the gun was adopted for the British Army. In trials in various countries, it proved superior to those of the Americans, Richard Jordan Gatling (1818-1903), William Gardner (1844-87) and Hotchkiss, and of the Swedish engineer, Thorsten Nordenfelt (1842-1920), and became the standard weapon of its kind for many armies. The amalgamated companies, with their works at Crayford and Erith, were incorporated with the Vickers company in 1897, under the name of Vickers, Son and Maxim, of which Maxim remained a director until 1911. While Maxim guns were being produced in large numbers, Maxim began to build his gigantic steam-driven "captive" flying machine at Baldwyn's Park, Bexley, Kent, and this attracted much attention. Later, he made a petrol engine-driven machine; parts of both are now in the Science Museum. The full tale of his inventions and of his ingenious ideas would make a volume, for, as he himself said, he was "a chronic inventor." He was a clever draughtsman, an outstanding mechanician, and something of a chemist and physicist. On one occasion, with the aid of a microscope and a micrometer, he solved in 24 hours a problem in explosives which had baffled the professional chemists. He was declared, in the Law Courts, to be "the first to combine nitroglycerine and true guncotton in a smokeless powder." A knighthood was conferred upon him in 1901. Towards the end of his life, he lived at Thurlow Park, Norwood, and he is buried in Norwood cemetery. His death took place on November 24, 1916.

THE LATE COLONEL R. E. B. CROMPTON.

IT is necessary to go back to the very early days of engineering to find a parallel in versatility to Colonel R. E. B. Crompton, C.B., F.R.S., whose death, we regret to record, took place on February 15, at his home, Azerley Chase, near Ripon. In his long life of almost unbroken activity, he achieved prominence in several diverse fields of engineering development, apart from possessing the unusual distinctions of having seen active service in both the Navy and the Army and of being personally associated with events so mutually remote, to modern minds, as the siege of Sebastopol and the introduction of the tank in land warfare. Those concerned with roads and the vehicles which use them will remember him as a successful pioneer of mechanical traction at a time when technical difficulties and vested interests rendered anyone who ventured to suggest the displacement of the horse liable to be stigmatised as a crank, if nothing worse. They will also recall his much more recent efforts to make the highways fit for motor vehicles to run on and the interest he showed in the development of those vehicles, especially for commercial purposes. Again, they will not forget the part he played in the design of that new and unusual weapon of war, the tank, the development of which, especially in recent years, has been so extraordinary. To electrical engineers he was the legendary, though living, figure who in the distant 'nineties of last century had preached the advantages of the direct-current system of distribution, and had worked energetically to prove those advantages in practice. If experience, to some extent, has proved him at fault, this does not prevent them from paying full tribute to his enthusiasm or from hailing him as the perpetual youth who never lost an opportunity of pointing out the important part that electricity could play in modern life. To yet another section, his principal claim to fame will be the work that he did in forming the British Standards Institution, and, later, the International Electrotechnical Commission, two bodies whose activities have had considerable influence, both on engineering progress and on international understanding.

Photo : Elliott & Fry.

THE LATE COLONEL R. E. B. CROMPTON.

Rookes Evelyn Bell Crompton was born at Sion Hill, Thirsk, on May 31, 1845. The first real event of his life was a visit to the Great Exhibition of 1851, where he was fascinated by the locomotives, machine tools and other plant. After a short time at a preparatory school, he accompanied his father to Gibraltar, when his Militia regiment was embodied on the outbreak of the Crimean War. There he succeeded in obtaining an appointment as midshipman in H.M.S. Dragon, and was thus fortuitously present at the fall of Sebastopol, receiving the Crimean medal and clasp for his services. He then returned to school, first at Elstree and subsequently at Harrow. During his holidays, he began experiments with a full-sized road engine, the greater part of which he made himself. These efforts were so successful that his father seems to have been uncertain whether he should adopt the army or engineering as a career. Eventually, however, the young man was gazetted to the Rifle Brigade, and, after a tour of regimental duty in India, was appointed to the staff of the Commander-in-Chief. Meanwhile, he had been re-designing his engine and soon succeeded in interesting the authorities in the suggestion that mechanical transport would be an efficient substitute for bullock trains.

The upshot was that Crompton was made Superintendent of the Government Train in the Indian Post Office, and that a 6-h.p. engine was ordered, the wheels of which were fitted with the large and thick rubber tyres that had recently been invented by R. W. Thomson, of Edinburgh. On its arrival, this engine was attached to wagons, which had meanwhile been built by Crompton in the Allighur workshops of the Department, and was tested on the Grand Trunk Road between Umballa and Kalka. In spite of the fact that the boiler was deficient in steaming capacity, owing to the use of wood instead of coal for which it had been designed, the results were so successful that Crompton was sent to England to confer with Thomson, and was armed with authority to order four more units. As a result, a machine was built, equipped with a Field boiler and fitted with tyres 6 ft. 2 in. in diameter, and 4¾ in. thick, with a tread of 15 in. This successfully hauled a load of over 40 tons at speeds up to 30 m.p.h., and, with a second of the same type, was subsequently used regularly between Rawal Pindi and Attock; so that, by the end of 1874, it had been established that steam haulage was three times as quick and half as expensive per ton-mile as bullock or horse transport.* It is not surprising, therefore, that, in 1875, a Government Committee reported in favour of this form of transport, and that a grant of 500*l.* was made to Crompton for his work. The sequel, however, was not so satisfactory. The assassination of the Viceroy and the retirement of the Commander-in-Chief and the Director-General of the Post Office, deprived the young inventor of the support he had been receiving in high quarters, and the attention of engineers was turned to railway development.

In 1876, Crompton retired from the Army, but returned to England to find that his hopes of developing road transport in this country were not realisable owing to the existing state of the law. In fact, it was not until 1900, when he raised a detachment equipped with portable searchlights, steam traction engines, and field telephones, for service in the South African War, that he was again actively engaged in this subject. At first this body of men did useful work in assisting the railway reconstruction parties, but subsequently the engines were organised into a mechanical transport corps for hauling guns, ammunition and other supplies. In this they were so successful that Crompton was sent back to England and entrusted with the design of an engine capable of hauling loads over the veldt; important features of this were the use of light steel castings and pressings, and the employment of wheels constructed on the suspension principle. Somewhat earlier, however, he had taken an interest in the lighter side of road traction, being a founder member of the Automobile Club of Great Britain and Ireland, afterwards the Royal Automobile Club, and designing a bicycle with large-diameter wheels and 9½-in. instead of 6½-in. cranks, to increase its climbing capabilities and reduce the fatigue of the rider.

His interest in motor traction drew his attention about this time to the condition of the roads. Between 1905 and 1908, he conducted a series of trials for the Royal Automobile Club to discover what could be done to mitigate the dust-lifting propensities of cars. He reached the conclusion, however, that it was the road surface itself that must be improved, while a further series of experiments showed that the treatment of the road metal with tar was the best solution of the problem. This work led, eventually, to the formation of the Road Board, of which he was appointed the first engineer, and to a systematic investigation of various proposed methods of surfacing. Valuable information regarding the effect of vehicles on the road was also obtained, the results being embodied in a paper read before the Institution of Mechanical Engineers* in 1913, for which he received the Starley Premium. He also acted as consulting engineer on road questions to many public authorities and private firms, both in this country and abroad. At the same time, he continued to take an interest in motor vehicles, and, shortly before the outbreak of the war of 1914-18, placed his services at the disposal of the authorities; though his suggestion that he should design a mechanically-propelled gun was not received with any great enthusiasm. In 1915, however, he was appointed technical adviser to a committee which had been formed to devise methods for attacking and crossing trenches and to design a mechanically-propelled vehicle for that purpose. As is well known, the outcome was the tank, in the development of which Crompton played a part which even now cannot be fully disclosed.†

We must now return to 1876. With a view to finding some position in which his mechanical know-

* See ENGINEERING, vol. 28, pages 106, 124 and 148 (1879).

* See ENGINEERING, vol. 96, pages 851, 865 (1913).
† See ENGINEERING, vol. 118, page 334, *et seq.* (1919).

ledge might be utilised, on his return from India he joined the firm of T. H. P. Dennis and Company, of Chelmsford, as a partner and was placed in charge of a department which had been recently opened to manufacture valves for their heating apparatus. He was among the first to utilise machine tools for this class of product, but, which was more important, the commercial side of his work brought him into close touch with Willans and other engineers. Another important event was a commission he received to install artificial lighting in a new pipe foundry at the Stanton Ironworks, Nottingham, so that production could be carried on continuously. After trying portable lamps and several forms of gas lighting, it was finally decided to employ electricity, Gramme dynamos and Serrin arc lamps being imported from France for the purpose. The experiment was so successful that not only were similar machines installed for other firms, but Crompton determined to manufacture the plant for himself. The result was the formation of Crompton and Company, one of the first of whose activities was to re-model the Serrin lamp, so as to eliminate the downward shadow that it cast and to render possible its independent regulation. The next step was to design dynamos of higher output than the Gramme machines, work in which he was ably assisted by Burgin. The first of these machines was built in 1880 and incorporated the important improvement of mounting the brushes on a rocker, so that the angle of commutation could be varied without having to alter the brush pressure. The design of the commutators was also improved by using mica instead of vulcanite or ebonite as an insulator.

About this time, Willans was developing his high-speed totally-enclosed inverted-type engines, and these were employed by Crompton for driving the dynamos used in the arc-lighting installations that he supplied to, among other places, King's Cross Station, London, Alexandra Palace, and the Town Hall, Birmingham. They were also exhibited at the Smoke Abatement Exhibition of 1881 and at the International Exposition held in Paris in the same year, where they obtained the first gold medal awarded for electric-lighting plant. In the latter machine the magnets were of wrought instead of cast iron, and of much larger cross-section than had been usual, two features which greatly improved the magnetic circuit. With the coming of the incandescent lamp, this side of the business began to grow, one of the first buildings to be lighted in this way being the Royal Courts of Justice, London. All the apparatus for this contract was manufactured by the firm, the switches and wall plugs being invented by the same Thomson with whom Crompton had been connected during his early days in India. A number of ship installations were also supplied and many private houses lighted. Although, technically speaking, the time was now ripe for the general introduction of the electric light, development was seriously impeded by the passing of the Act of 1882, Crompton therefore turned his attention to other countries and was fortunate in obtaining the opportunity of carrying out a large-scale experiment in Vienna, where a conflagration at the Opera House had called attention to the dangers of gas. A station containing six 150-h.p. sets, running at 150 r.p.m., was erected in a central position and used to supply not only the Opera House but other important buildings. It operated on the five-wire system at a pressure of 440 volts across the outers. Similar work was carried out in Budapest and other south-east European cities in face of strong Continental competition.

As a result of this experience, a station was erected, in 1886, on the Kensington Court estate, in the West End of London, where the existence of a subway enabled a supply to be given without opening up the roads. The initial capacity of this plant, which, being established by Provisional Order, may not unreasonably be claimed to be the parent generating station of Great Britain, was 35 kW and distribution was effected through bare copper strip carried on porcelain insulators fixed to the walls of the subway. The relative advantages of this system and Ferranti's high-pressure idea were fully discussed in papers read before the Institution of Electrical Engineers* in 1888 and before the Institution of Civil Engineers* in 1890. The latter, which gained a Telford Medal and Premium, was the first communication to be made to that institution on this branch of engineering. Figures were given showing that the coal consumption per kilowatt-hour generated was 8·8 lb., the cost being 1·83*d*. As the load factor (a term then used for the first time) varied between 16·6 per cent. in the winter and 5 per cent. in the summer, the necessity was stressed of improving it by persuading customers to use electricity for purposes other than lighting. The development of plant of this type containing a number of small sets which could be started up and stopped as the load varied, and thus operated at maximum efficiency, was greatly assisted by the decision of the Board of Trade to limit the area that might be supplied from one station, and, to a certain extent, to the initial troubles connected with Ferranti's attempt to employ alternating current. On the other hand, Crompton himself recognised that the latter was the proper system to use for the generation and transmission of power on a large scale, even though he qualified this recognition by pointing out, as late as the spring of 1931, that interest in direct-current was reviving and that its employment was likely to be stimulated by the development of the mercury rectifier and other types of transforming plant. Moreover, he always held that alternating current was more dangerous and less reliable.

For many years Crompton's activities were closely concerned with the manufacturing firm that he had founded at Chelmsford and the business of which was largely concerned with the production of plant for generating stations, as well as motors, switchgear, instruments and especially searchlight projectors, for use both on ship and shore. Unfortunately, these activities were not uniformly successful financially, and when, in 1912, a financial crisis over certain Indian contracts necessitated a reconstruction, he severed his connection with the concern. This severance was not final, however, for when, in 1927, the firm was amalgamated with that of Messrs. F. and A. Parkinson, Crompton again joined the board and was acting as a director at the time of his death.

No memoir of Crompton would be complete without some reference to his work in the field of standardisation. He was one of the first representatives nominated by the Institution of Electrical Engineers to the Main Committee of the Engineering Standards Committee on its foundation, in 1901; while, as a result of a paper that he read at the International Exhibition at St. Louis, in 1904, he was asked to undertake the task of organising a permanent International Electrotechnical Commission. The first plenary meeting of this body was held in London in 1906, with Kelvin as president and Crompton himself as honorary secretary, and its British National Committee is now the Sectional Electrical Committee of the British Standards Institution. Further, he did a great deal of work in improving the shape and fit of standard screw threads so as to secure international agreement and, in conjunction with Mr. Clements, designed a new form of thread known as the British Standard Fine, to take the place of the Whitworth thread on automobiles and electrical plant, for which the latter was considered to be too coarse. During the war of 1914-18 he was a member of a Committee set up by the Ministry of Munitions to advise on the interchangeability of screw gauges for the screwed parts of shells, fuses and other materials, and, in conjunction with Mr. W. A. Price, devised a gauge by which the accuracy of the pitch of both external and internal threads could be ascertained within very close limits.

As a continuation of his early career as an Army officer, for many years Crompton held a commission in the London Electrical Engineers (Territorials) and commanded the unit from 1901 to 1910, when he became Honorary Colonel. For his services in the South African War he was made a Companion of the Bath. He was elected a Fellow of the Royal Society in 1933. He became a member of the Institution of Civil Engineers in 1886; he delivered the James Forrest Lecture in 1905, and had served on the Council. He joined the Institution of Mechanical Engineers in 1877, and was probably the last survivor of the small band of its members who took part, in that year, in the migration of the Institution from Birmingham to London. His connection with the Institution of Electrical Engineers began in 1880, when he was elected an associate, being transferred to the class of member in the following year. He served as president of this body in 1895 and 1908, being the senior past-president at the time of his death. He was elected an honorary member in 1923 and received the Faraday Medal in 1926. He was first president of the Institution of Automobile Engineers, the Institution of Highway Engineers, and of the Commercial Motor Users' Association. He was also president, in 1918-19, of the Junior Institution of Engineers, and, in his address to them, went so far as to suggest that the social progress of a community was to be measured by the development of its roads, rather than of its railways. He was also president of Section G of the British Association in 1903, was a member of the Screw Gauge Committee of that body, and had served on the Executive Committee of the National Physical Laboratory.

In spite of these varied claims to distinction, however, Crompton remains something of an enigma. Useful as his activities undoubtedly were, he cannot be placed in the highest class, either as an engineer or as a scientist. In mechanical transport, it is true, he was definitely before his time, and suffered accordingly, but when that time came his lack of technical knowledge proved an obstacle which prevented him from doing as much as he otherwise might. He himself contributed little of fundamental importance to the development of electrical engineering. He had vision, but his ideas were largely worked out by others, and, though undoubtedly he was a source of inspiration, his suggestions led to no great discoveries. He must be credited with a great deal, yet the greater wonder is that he did not do more.

The portrait reproduced on the opposite page was taken last year, on his 94th birthday.

* See ENGINEERING, vol. 45, pp. 392, 413 and 436 (1888).

* See *Proceedings of the Institution of Civil Engineers*, vol. 106, page 2 (1891).

THE INSTITUTION OF MECHANICAL ENGINEERS.

THE annual general meeting of the Institution of Mechanical Engineers was held on Friday, February 16, at Storey's-gate, St. James's Park, Westminster, and was preceded by a well-attended informal luncheon. The chair at the meeting was occupied, during the initial proceedings, by the retiring President, Mr. E. Bruce Ball, and subsequently by his successor, Mr. Asa Binns.

THE LATE COL. R. E. B. CROMPTON.

After the transaction of the formal business, the President referred in appreciative terms to the work of the late Colonel Rookes Evelyn Bell Crompton, C.B., F.R.S., who had been a member of the Institution for 63 years, having joined it as far back as 1877. A message of condolence had been sent to his relatives.

AMENDMENT OF BY-LAWS.

The President then announced that, in view of the fact that many of the younger members had been called up for service with the Forces, and that war conditions were likely to cause hardship in other ways, the Council had decided to amend the by-law dealing with subscriptions. This amendment had been submitted by circular to all members and was, briefly, to the effect that the Council should be given power to reduce or remit, at their discretion, the annual subscription or arrears of subscription of a member of any grade who might be unable to pay it by reason, directly or indirectly, of any war in which Great Britain was engaged. The President, therefore, proposed, and Mr. E. W. Moss seconded, that the amendment be ratified. The motion was carried unanimously.

HONORARY LIFE MEMBER.

The President next announced that the Council had that day conferred upon Sir H. Nigel Gresley,

C.B.E., D.Sc., the honorary life membership of the Institution. Sir Nigel, who had joined the Institution in 1907, had been president for the year 1936 and had since served on the Council for three years as past-president.

ANNUAL REPORT.

The President moved that the Annual Report be adopted. This motion, having been duly seconded, was put to the meeting and carried unanimously. Mr. A. P. Bale, discussing the report, thought that section dealing with the library did it less than justice. The library was the only section of the Institution which had functioned as usual since the outbreak of war, and he would like to acknowledge the invaluable services rendered. There was no mention in the report of the informal meetings, the cessation of which he considered was much to be deplored. There appeared to be no sound reason for discontinuing the informal meetings of the Institution, even though the ordinary meetings could not be held.

The President replied that the Council were gratified to find that the maintenance of the library services had been appreciated by members and he would add that they had been largely made use of by various important outside organisations. With regard to the continuance of informal meetings, various administrative difficulties had existed: members would see from the *Journal* that they were being resumed and that ordinary general meetings also would be held in the evenings in accordance with previous practice.

The following is a summary of the report :—

The ninety-second annual report, for the year ended December 31, 1939, showed a net increase on the roll of membership of 450 names, the total having reached 13,679. There were increases in all the grades except those of Companion and Student, the largest increase being in Associate Members. Mr. J. E. Montgomrey, B.Sc. (Eng.), had been appointed Secretary. Among the losses by death, 145 in number, were Eng. Vice-Admiral Sir Robert B. Dixon, K.C.B., D.Eng., Vice-President; Mr. Robert Dumas, member of the Cutting Tools Research Committee since 1919; Mr. Benjamin Irving, Member of Council from 1934 to 1938; Mr. J. A. Vaughan, for several years a member of the South Africa Advisory Committee; and Mr. Richard Williamson, Member of Council from 1917 to 1930. The total revenue for the year ended December 31, 1939, was 41,397*l.*, as against 40,238*l.* in the previous year. The balance of revenue over expenditure was 45*l.*, compared with 350*l.* for 1938. Nothing had been carried to the General Reserve Fund this year. The sum of 567*l.* had been expended on air-raid precautions, the Westminster City Council having scheduled the Institution building as a public air-raid shelter, available both by day and night for 210 persons. During the year, grants amounting to 1,957*l.* were made to the branches and graduates' sections, exclusive of the administrative and other expenses at headquarters. The Central Register for National Service, restricted to corporate members and graduates of the Institution, included some 6,600 names, many others, however, being already in Government service or engaged on work of national importance. A new seal had been prepared, following the grant of a coat by the College of Arms. The lower meeting room of the Institution building had been panelled throughout and bookcases had been fitted to give additional accommodation for the library.

Two new specialised groups had been formed, namely, a Hydraulics Group and a Manufacture Group. Three new Committees had been set up. These were the Coal and Gas-Engines Committee under the chairmanship of Wing Commander T. R. Cave-Browne-Cave, C.B.E.; an Exploratory Committee re Heat Transfer in Boilers, under the chairmanship of Major William Gregson, M.Sc.; and a Joint Standing Committee on Research of the Institution of Mechanical Engineers and the Institution of Production Engineers, under the chairmanship of Mr. E. Bruce Ball. The Welding Research Committee had been dissolved in view of the extension of the research programme of the Institute of Welding, but a small Pressure Vessels and Piping Research Committee had been formed, under the chairmanship of Dr. S. F. Dorey, which would collaborate with the Institute of Welding on matters of common interest. The Sub-Committee on Carbide Tools, under the chairmanship of Mr. J. M. Newton, B.Sc., was considering the question of experimental research in conjunction with the work of the Joint Standing Committee on Research. The Research Committee on High-Duty Cast Irons for General Engineering Purposes, under the chairmanship of Dr. H. J. Gough, M.B.E., F.R.S., had continued its work and it was hoped that a second report would be presented shortl The Pipe Flanges Research Committee, under the chairmanship of Dr. H. L. Guy, F.R.S., had completed practically all the experimental work envisaged and the preparation of a final report was receiving attention. The Exploratory Committee on Splined and Serrated Shafts and Hubs, under the chairmanship of Dr. H. J. Gough, M.B.E., F.R.S., had prepared a scheme of experimental work for submission to the Council. A second annual meeting of the two main research committees of the Institution of Civil Engineers and the Institution of Mechanical Engineers had taken place. The sub-committee appointed to revise the Refrigeration Committee's charts, under the chairmanship of Dr. Ezer Griffiths, F.R.S., had completed a report and some of the charts had also been completed.

A research was being conducted in the University of Sheffield, by Professor H. W. Swift, M.A., D.Sc., and Dr. John Dick, B.Sc., on the cyclic movements in journal bearings. Short notes of researches in progress, or recently completed, in the laboratories of universities and technical colleges, had been published in the *Journal*. The appeal to commemorate the Silver Jubilee of the Benevolent Fund by raising 10,000*l.* additional capital had so far resulted in the receipt of 2,828*l.*, and further subscriptions would be very welcome. The Fund, during 1939, had distributed 2,545*l.* among 68 recipients, but, owing to lack of funds, the Committee of Management were unable to deal as generously as they would have wished in some instances. The Institution had continued to provide the accommodation for the Fund and all clerical assistance in connection with its work.

APPOINTMENT OF AUDITOR.

It was proposed by Principal G. F. O'Riordan, B.Sc. (Eng.), F.R.S.E., and, after seconding, unanimously approved, that Mr. Raymond Crane, F.C.A., be re-appointed to audit the accounts of the Institution for the coming year.

BENEVOLENT FUND.

Major William Gregson, on behalf of the Committee of management, emphasised the appeal for increased support of the Benevolent Fund of the Institution made in the Annual Report, his main argument being that more general action on the part of members would place the Fund in a position in which further appeals would be unnecessary for a long time to come.

PRESENTATION OF PRIZES.

The Council awards for papers were then presented by the President. These were :—The Thomas Hawksley Gold Medal and Premium and a bronze replica of the gold medal, to Mr. J. J. P. Doland and Mr. W. G. Jackson, B.Sc., for their paper on "An Investigation into the Permissible Load-Carrying Capacity of Steel Wire Ropes, with special reference to Deep-Level Winding on the Witwatersrand Goldfields"; the George Stephenson Prize, to Dr. Adolf Meyer, for his paper on "The Combustion Gas Turbine: Its History, Development, and Prospects"; the Dugald Clerk Prize, to Dr. F. W. Lanchester, F.R.S., for his paper on "The Energy Balance Sheet of the Internal Combustion Engine"; Water Arbitration Prizes, to Mr. Alex Taub for his paper on "Cylinder Bore Wear," and to Mr. S. A. Wood, M.Sc., and Mr. A. Bailey, M.Sc., for their paper on "The Horizontal Carriage of Granular Material by an Injector-Driven Air Stream"; the Starley Premium, to Mr. E. C. Ottaway for his paper on "Motor Transport"; Herbert Akroyd Stuart Prizes, to Dr. E. Giffen, M.Sc., and Dr. A. W. Rowe, B.Sc., for their paper on "Pressure Calculations for Oil Engine Fuel-Injection Systems," and to Professor S. J. Davies, D.Sc.(Eng.), Ph.D., for his paper on "Recent Developments in High-Speed Oil Engines"; a Thomas Lowe Gray Prize, to Mr. A. H. Goodger, M.Sc.Tech., for his paper on "The Examination and Tests of Welded Parts for Steam Power Plant"; T. Bernard Hall Prizes to Mr. O. A. Price, for his paper on "Vortex Pumps, or Slip in the Centrifugal Pump"; and to Mr. C. W. Newberry, B.Sc., for his paper on "An Investigation into the Occurrence and Causes of Locomotive Tyre Failures."

The Graduates' and Students' prize list comprised the following :—Mr. W. O. Skeat, B.Sc., for his paper entitled "Some Notes on Printing Machinery"; Mr. W. H. Darlington, M.Sc., for his paper on "Surface Condensers"; Mr. L. J. Kastner, M.A., M.Sc., for his paper entitled "Cylinder Wear in Motor-Car Engines"; Mr. A. C. Murray, for his paper entitled "The Construction of Steam Vessels"; Mr. G. H. Rawcliffe, M.A., for his paper entitled "Some Mechanical Characteristics of Rotating Electrical Machinery"; and Mr. Donald Bradshaw, for his paper on "Engineering and the Rubber Industry." The Hele-Shaw National Certificate Prize was awarded to Mr. William F. Willbond, a student at Leicester College of Technology and Commerce, who was trained in the engineering workshops of Messrs. Hill and Herbert, 15, Stone Bridge-street, Leicester.

At this point, the meeting departed from normal procedure in that the retiring President, Mr. E. Bruce Ball, delivered his Presidential Address, which, but for the outbreak of war, would have been given at the beginning of the session. The address, which was entitled "The Influence of the Mechanical Mind on the Development of Irrigation through the Ages," will be reprinted in a subsequent issue of ENGINEERING.

ELECTION OF OFFICERS, ETC.

The Secretary then declared the result of the ballot for the election of officers of the Institution. This was as follows :—President, Mr. Asa Binns; Vice-Presidents, Mr. Sterry B. Freeman, C.B.E., and Professor F. C. Lea, O.B.E., D.Sc.; Members of Council, Lt.-Col. Lord Dudley G. Gordon, D.S.O., Mr. A. J. Grant, Wh.Ex., Major William Gregson, M.Sc., Mr. A. C. Hartley, O.B.E., Mr. F. W. Hawksworth, Mr. H. R. Ricardo, B.A., F.R.S., and Mr. B. W. Pendred (associate member). The three immediate past-presidents and the chairmen of the branches would serve on the Council as customary.

Mr. E. Bruce Ball, inducting Mr. Asa Binns into the presidential chair, congratulated him on his election and felt confident that his knowledge of affairs and previous experience on the Council well fitted him for the office of President.

Mr. Binns, on assuming the chair, said that he appreciated the great honour conferred on him by his election to this important office. He would do his best to deserve it, and knew he could rely on the support of the staff, and the members.

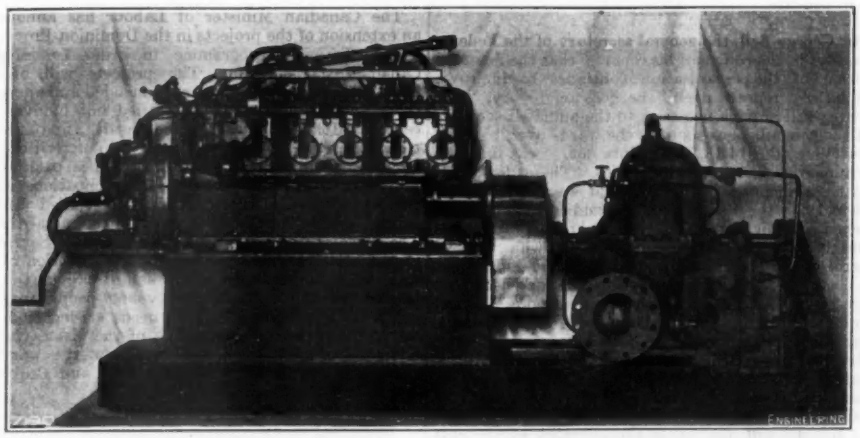
Mr. Loughnan St. L. Pendred, O.B.E., past-president, said he had the pleasant double duty of thanking Mr. Bruce Ball, on behalf of the members, for his consistent services to the Institution during his year of office, and of proposing a vote of thanks for his presidential address. In this address, however, Mr. Bruce Ball had modestly refrained from alluding to the great part he himself had played in hydraulic engineering. The fact remained that for the past twenty years he had been a leading light in the industry.

After Professor A. L. Mellanby, D.Sc., LL.D., had seconded the vote of thanks in appreciative terms, it was submitted to the meeting and carried with acclamation. Mr. Bruce Ball, in a brief reply, alluded to the great pains which had been taken by the engineers of the United States in preparing an excellent programme for the Summer Meeting, which, unfortunately, had to be cancelled on the outbreak of war.

INSTITUTION OF NAVAL ARCHITECTS.—The Council of the Institution of Naval Architects has awarded the premium of the Institution for 1939 to Mr. A. Nicholls, R.C.N.C., for his paper, "The All-Welded Hull Construction of H.M.S. Seagull." The Wakeham Prize for 1939 has been awarded to Mr. A. Emerson, B.Sc., for his paper, "The Effect of Shape of Bow on Ship Resistance."

ALUMINIUM SECTIONS.—A new book of 205 pages, entitled *Aluminium Sections*, just issued by Messrs. The British Aluminium Company, Limited, Raven Hotel, Castle-street, Shrewsbury, Salop, gives some conception of the extent to which drawn and extruded sections in aluminium and aluminium alloys are produced for various industrial applications. To the more familiar shapes, namely, tubing, bars, angles, channels, tees, lap plates, edgings and mouldings, are added the growing range of sections used for architectural, shop-fitting and other miscellaneous purposes. Attention is drawn to advances in technique, particularly in the production of hollow sections, some interesting specimens of which are illustrated. The volume is thumb-indexed in divisions and a complete index to the section numbers is also included. It is bound in strong cloth boards by the Spirax helical-wire method and opens flat for easy reference. Gummed linen guards are provided at the end of the volume for attaching supplementary pages, which will be issued from time to time.

PETROL-ENGINED PUMPING SET.



PETROL-ENGINED PUMPING SET.

A LARGE demand has arisen for pumping plant in connection with A.R.P. equipment, and a set of this kind for fire-fighting and general service, recently supplied by Messrs. The Pulsometer Engineering Company, Limited, of Reading, may, therefore, be of interest. The pumping set, illustrated by the photograph reproduced on this page, consists of a Pulsometer-type HSRB.6 pump, driven by a petrol engine, and is designed to deliver 750 g.p.m. against a total head of 340 ft. when running at 1,500 r.p.m.

The pump is of the two-stage type with horizontally-split casing, the impellers being arranged back to back, to reduce hydraulic thrust. The casing is of cast iron, while the shaft is of steel protected by bronze sleeves between the supporting bearings. The impellers are of gunmetal. The rotating unit of the pump is supported in ball and roller bearings. There is a rotary-type exhauster driven from an extension of the pump shaft by means of a Vee-belt, the exhauster being used for priming the pump. The materials and general construction of the exhauster are similar to those used in the main pump. The exhauster runs continuously, but when the pump is primed, an automatic valve isolates the exhauster from the pump, except for the passage of a small quantity of cooling water which passes continually through the exhauster to prevent over-heating.

The driving unit is supplied by Messrs. The Parsons Engineering Company, Limited, of Southampton, and comprises one of their well-known six-cylinder M-type engines, having an output of 110 h.p. at 1,500 r.p.m. when running on petrol. Starting is by hand at the forward end, and the plant is provided with 12-volt electric starter as well. The engine is fitted with high power down-draught carburettors, impulse-driven magneto, and centrifugal-type water circulating pump, and is of a type developed for continuous high-power, high-speed duties. A special floating coupling is used which enables the pump rotor to be lifted vertically when the top half of the casing is removed. The whole plant is mounted on a rigid fabricated-steel bed built up from steel channels and bars as shown, the engine being carried on cast-iron stools, and is representative of a number of similar plants of various sizes recently produced for A.R.P. and similar service.

LETTERS TO THE EDITOR.

IMPROVED RESULTS FROM A PETTER SUPERSCAVENGE ENGINE.

TO THE EDITOR OF ENGINEERING.

SIR,—I have read with interest the correspondence in connection with the tests that I carried out with a four-cylinder Petter engine, and Professor Davies' tests with a two-cylinder Petter engine which embodied the Kadenacy modifications. We are in the habit of referring to the reading given by a thermometer placed in the exhaust branch of an engine as the exhaust temperature but, as is generally known, this is not the temperature of the exhaust gases. The reading of the thermometer is influenced by the actual temperature of the exhaust gases, which varies during the exhaust period, by the temperature and amount of scavenge air, and by the periods of opening and the phasing of the exhaust and scavenge ports or valves; as well as by the position of the thermometer in the exhaust branch. At the best, such a thermometer can give only a time-mean temperature of the gases in contact with it.

In my opinion, therefore, no reliable conclusions can be drawn by using the "exhaust" temperatures alone for comparison with the results obtained from other engines, particularly if the engines are not identical in design. In this connection, therefore, I am in general agreement with the views expressed by Mr. Green in your issue of January 26.

Yours faithfully,
C. J. HAWKES.

University of Durham,
King's College,
Newcastle-on-Tyne, 2.
February 13, 1940.

THE KADENACY SYSTEM OF SCAVENGING.

TO THE EDITOR OF ENGINEERING.

SIR,—The recent discussion in your columns regarding the Kadenacy system of scavenging appears to have been confined largely to the somewhat abstruse question of the means by which a vacuum is produced on the discharge of the exhaust gases from an engine cylinder, the way in which the said vacuum is to be made use of in an actual engine having been given but little attention.

Whether the vacuum is produced by the exhaust gases escaping *en masse* from the cylinder and leaving behind them a depression, or whether it is solely due to the negative reflection of a pressure pulse from the open end of a pipe, is of secondary importance as far as the engine is concerned; but if this vacuum is to be used most efficiently, the period during which it occurs should be under the control of the designer. Whatever the effect of the exhaust-pipe length on the magnitude of the depression, it seems certain that it can exert a powerful influence both on the duration of the "vacuum period" and on the interval between the point of opening of the exhaust valve and the instant when the pressure in the cylinder falls below atmospheric. For this reason a careful study of the effects of alterations in exhaust-pipe length in any engine utilising the energy of the escaping exhaust gases would appear to be well worth while, and until such a study is available, the relative importance of the various components of the exhaust system will be difficult to assess.

It appears to the writer that much useful information could be gained by comparing the performance of a Kadenacy engine from which the exhaust pipe had been removed with the performance of the same engine with the exhaust pipe usually fitted. Have any of the contributors to the discussion made such a test?

Yours, etc.,
L. J. KASTNER, M.A.

Hawthornden,
Marple, Cheshire.
February 6, 1940.

[As Mr. Kastner's letter contains the question whether tests have actually been made on Kadenacy engines without an exhaust pipe, we have submitted it to Professor Davies, whose reply is given below.—ED., E.]

TO THE EDITOR OF ENGINEERING.

SIR,—In his letter, Mr. Kastner asserts that the manner of producing the depression in the cylinder (whether by the exhaust gases escaping *en masse* and leaving behind them a depression, or due to the negative reflection of a pressure pulse from the open end of a pipe) is of secondary importance. In an engine working on the Kadenacy system, this question is of primary importance, since, although pressure waves may be present in the pipe, the exhausting *en masse* dominates and determines the function of the exhaust pipe. He rightly says that a careful study of the effects of alterations in exhaust-pipe length is of interest, and this study has, of course, been made. But the results cannot be separated from the functions of the other elements, since the Kadenacy system involves a combination of features, such as exhaust opening, admission opening, and the proportions of the exhaust organ, all of which must be in the correct relationship one to another. If, for example, there is no exhaust pipe, the relationship between the other elements must be arranged accordingly.

In my report in ENGINEERING, June 18 and 25, 1937, I gave, in my Test No. 2, results from one engine without an exhaust pipe. Further, I have seen the exhaust pipe removed from a second engine, that of my Test No. 9, and the engine ran and delivered power; but since the other elements in that engine were intended to be combined with an exhaust pipe, the performance was, therefore, inferior to that to be expected when these were arranged for an engine with no exhaust pipe. In a third engine, the removal of the exhaust pipe at full load had no effect.

In conclusion, I would emphasise that, since the actions depend fundamentally on the exhausting *en masse* of the gases, the high momentum of these gases, both within the cylinder and outside, that is, in the exhaust organ or beyond it, should be considered.

Yours faithfully,
S. J. DAVIES.

University of London, King's College,
University of Bristol.
February 15, 1940.

A.R.P. LIGHTING IN GERMANY.

TO THE EDITOR OF ENGINEERING.

SIR,—We have read with interest the editorial on "A.R.P. Lighting in Germany," in your issue of February 2, on page 118, particularly the part devoted to pilot lights for assisting road users in black-out conditions. From your description, the use of 4-in. slots of light, acting as pilot or guide lights, and not as illuminants, is similar in principle to the system we have advocated since the beginning of the war, but, judging from your description, the German pilot lights do not show a red light from the back although they do emit light from the bottom, which partially illuminates a ground area of about 90 sq. ft. It is a red dot from the back of the lamps, however, that unmistakably locates the right-hand curb on the off side of the road. The successive white dots on the driver's left hand have one meaning only, and indicate the course of the near curb.

The small guide lights give the definite position of road boundaries, both near and ahead, without confusion with existing traffic lights at main crossings. They may, of course, be adopted in various ways to signify pedestrian crossings. Pedestrians and drivers are freed from the loss of location by these purely directional lights, however small, and the motorist is not preoccupied by the question whether, say, a white centre line is the offside curb or not. Both sides of his course are clearly indicated.

The modified illumination from underneath the German pilot lamps is not, in our opinion, consistent with the aim of the pilot light, which is to give absolute direction in the absence of illumination. The system of pilot guide lights, which we hope will be introduced, gives no illumination and the lamps may be left on safely during an air raid; when, of course, their value would be a maximum. The small guide lamps are designed for electricity or gas. For districts without either of these supplies, oil-lamps or torch-battery ones may be used. The gas and the oil types are intended to burn continuously night and day, to reduce the cost of maintenance.

It has been pointed out to us that the newly-authorised modified illumination serves the same end, but we feel that a guide light must be better than an indefinite glow, and in any case, if it is thought to be less effective, it cannot entail more risk from the enemy, and might, therefore, be given a practical trial.

Yours faithfully,
For HENRY LINDSAY, LIMITED,
HENRY LINDSAY,
Director.

47, Queen's-road,
Bradford.
February 5, 1940.

LABOUR NOTES.

AT a conference in London on Thursday last week representatives of the Shipbuilding Employers' Federation and the Confederation of Shipbuilding and Engineering Trades further discussed the application of the shipyard unions for increases of wages to meet the higher cost of living due to war conditions. At the close of the meeting, it was officially stated that it had been agreed to recommend, to the constituent bodies on both sides, the following terms of settlement :—A war bonus of 5*s.* a week for 47 hours for male employees 21 years of age and over, whether time workers or piece workers, as from the beginning of the first full pay week following February 15. A proportionate advance to junior male employees in accordance with the existing agreement between the Employers' Federation and the Confederation of Unions.

Industrial News, a publication of the British Trades Union Congress, states that difficulties with regard to the superannuation claims of certain classes of workers volunteering for munition work, have been cleared up following discussions with the Ministry of Health. The view of the Trades Union Congress was that men transferring from other occupations—for example, engineering workers in luxury industries and in public services—to munition work should be treated in the same way as men in the same categories who joined the armed forces. In other words, the trustees of any superannuation or pension scheme or sick fund to which they belonged should be authorised to suspend, without loss of rights, payments during the period in which they are certified to be engaged in the manufacture of munitions. Under Section 14 of the Local Government Staffs (War Service) Act, 1939, the Minister of Health is empowered to recognise as "war service" for the purposes of that Act any employment during the period of the emergency which he considers may properly be treated for the purposes of the Act in the same manner as service in His Majesty's Forces. The superannuation rights of any employee of a local authority who ceases to serve in his civil capacity in order to undertake war service are preserved by Section 3 to 7 of the Act.

Congress, it is stated, have been informed that the Minister will be prepared to consider applications, from local authorities for recognition as war service for purposes of the Act, in regard to skilled and semi-skilled employees, who, with the consent of their authority, undertake employment in munition works. Recognition, it is added, would normally be subject to the following conditions :—(1) The men are surplus to the essential requirements of the authority ; (2) the arrangements for their transfer are made with the concurrence of the local branch of the Ministry of Labour.

In the February issue of *Man and Metal*, the journal of the Iron and Steel Trades Confederation, the editor discusses an interesting point relating to the application of the Factories Act. A workman at Gowerton, South Wales, had, it appears, fixed a chain to a steel girder which was not capable of carrying the weight with the result that the chain broke and the girder fell on the foot of a mason who was working near the spot. The mason's foot had subsequently to be amputated. The man who had fixed the chain to the girder was charged before the local bench with a breach of the Factories Acts. The inspector who prosecuted, stated that the case was brought, not with the object of extracting a heavy penalty, but mainly to advertise the fact that the free and easy practice of the past was not allowed, and that workmen, as well as employers, had their responsibilities. He was satisfied, he added, that the firm had taken all necessary steps to safeguard their workmen, and that they could not be held responsible for the accident.

In defence of the workman, it was stated that he was a bar loader. He had had nothing to do with the job that day, but had assisted in moving the chain from the end of the girder to the middle. The magistrates ruled that, by doing so, he had made himself responsible, and should have known that the chain was too weak to hold the load. He was ordered to pay the costs, which amounted to 2*l.* 7*s.* 6*d.* "We desire to warn our members," *Man and Metal* says, "of the danger involved and the responsibility that may fall on their shoulders for any accident that may result as a consequence of doing work not recognised as part of their job."

The report of the General Federation of Trade Unions for the fourth quarter of 1939 states that 92 societies are affiliated to the organisation—57 on the higher scale, 33 on the lower scale, and two on both scales. The membership on which contributions are based is 341,458. Of that number, 220,409 members are on the higher scale, 110,966 on the lower scale, and 10,083 on both scales. During the three months, 6,315*l.* 16*s.* were received in contributions, and 114*l.* 7*s.* 6*d.* paid out in benefits.

Mr. George Bell, the general secretary of the Federation, says in the course of his report : that the financial position of the organisation continues to improve. "If history repeats itself," he goes on to say, "the reserves will prove a necessity to the affiliated societies and their members as soon as the war is over." "The Great War of 1914-18," he points out, "was followed by numerous industrial difficulties. These developed into trade disputes on questions of wages and hours, and in 1920, the Federation's expenditure on benefits reached its highest peak. Some of these disputes could have been prevented had those who were in control of our economic life used foresight and sought the healthy co-operation of the trade unions. Had there been less academic discussion and more practical economic frankness, both industry and the people of this country might have been better placed now. Individualism, pushed to the point of fanatical introspection and paying little regard to the welfare of others, has been one of the greatest dangers, because it ultimately produces a dictator. It is to be hoped that history will not repeat the mistakes of the past which would again cause industrial strife after this war." At the end of 1939, the funds of the Federation had reached 295,815*l.* 7*s.* 6*d.*

The weekly organ of the International Labour Office at Geneva states that a system of short-time relief, similar to that in Germany, has been established in the Protectorate of Bohemia-Moravia. It is payable to any person insured against sickness who, owing to a shortage of work, is employed in two consecutive weeks for less than 78 hours but more than 16 hours and, for this reason, has his remuneration reduced. The relief is subject to a means test. It amounts to 50 per cent. of the difference between the actual remuneration and that which the worker would have received in a full 80-hour fortnight, together with an additional 10 per cent. for each dependent, up to a maximum of 80 per cent. Absolute maxima are further laid down in certain cases in a circular of the Minister of Social and Health Administration of November 23, 1939.

The maximum weekly amount is 50 crowns for a worker who receives 150 crowns for a full 48-hour week, subject to an increase, if there are dependents, up to a maximum of 75 crowns ; if the earnings for a 48-hour week are from 150 to 250 crowns, the corresponding maxima are 80 and 120 crowns respectively, and if they are over 250 crowns, the maxima are 100 and 160 crowns, respectively. A further Circular applies these measures to workers in textile and glass works and to those engaged in leather work for factory-made shoes and gloves.

The Commissioner for the German Four-Year Plan has issued a Decree providing that the Minister of Economic Affairs shall adopt measures for increasing the output of industry by means of the training and advancement of skilled workers. The Industrial Code is to be amended accordingly. The Decree, it is explained, was necessitated by the fact that the legal provisions on which vocational training in trade and industry had previously been based were not fully adapted to the new developments that have taken place since the National-Socialist régime began in 1933. Thus, it had been found impossible to extend to the rest of Germany the validity of the standard contract for handicrafts apprentices which was introduced some months ago into Austria and Sudetenland. Moreover, the application of the provisions reducing apprenticeship training to three years has encountered difficulties, because the provisions of the Industrial Code rendered impossible the adoption of certain measures for increasing output.

The Council of People's Commissars in the Soviet Union has framed conditions under which certain undertakings may be permitted to work on official holidays. The official public holidays are January 22, May 1 and 2, November 7 and 8, and December 5. The People's Commissars and other central bodies in the Soviet Union and the Federated Republics are empowered to allow work on holidays in undertakings working on continuous processes the activity of which cannot be interrupted for technical reasons or because they have to meet the requirements of the population. On the same days permission may also be given to carry out repair work urgently needed for the maintenance of production and loading and unloading operations connected with transport by rail and water. The lists of undertakings and workshops in which work will be allowed on public holidays are to be approved by the People's Commissars, in agreement with the trade union central committees concerned.

The Canadian Minister of Labour has announced an extension of the projects in the Dominion-Provincial Youth Training Programme in order to improve Canada's war position. The projects will operate in all Provinces which have recommended and approved them and the work will be carried out in over 400 centres. Instruction will include health, first-aid and citizenship training and other group activities. In training for industry, special attention is paid to the provision of sufficient training for occupations where there will be an increased demand for skilled workers in war contract work, particularly in the metal trades. The survey to be made by the Employment Service of Canada will provide the basis for the direction of the training to occupations where skilled labour is most needed. Training courses for young people in rural areas are in progress. As the needs arising from the war become clear, the curricula of the classes will be adapted to meet them and to follow the war-time policies determined by the Dominion and Provincial Departments of Agriculture.

A communication received by the International Labour Office in Geneva states that a Legislative Decree of November 23, 1939, promulgated on December 5, provides for an emigration tax in Bohemia-Moravia. All persons who emigrate after March 14, 1939, from the Protectorate, in order to proceed to a country other than Germany, are subject to the tax. The Decree defines the emigrants who are liable to the tax. Exemption is granted to persons who are exempt from income tax, persons exempted by the Ministry of Finance if in the opinion of the Ministry the emigration of these persons is in the interest of the Protectorate or for important economic reasons, and persons whose property does not exceed an amount of 200,000 crowns and whose annual taxable income does not exceed 140,000 crowns. The tax is levied on the emigrants' total property, both movable and immovable, with the exception of rights to pensions, invalidity benefits or similar payments, or pensions representing payments for work carried out. The rights accruing under private life insurance, if the policy is for a sum of less than 50,000 crowns, and rights accruing under compulsory social insurance and other insurance systems are also exempt.

The rate of tax is 25 per cent. of the net value of the whole of the property liable to tax. It is due on the day the emigration takes place. In the case of those who had emigrated before the coming into force of the Legislative Decree of November 23, 1939, the emigrant is liable to the tax on the day on which the Decree comes into force, namely, December 5, 1939. Everybody liable to the tax must make a written declaration 30 days before the emigration to the financial authority of first instance. This declaration must contain a statement of all property liable to tax. The tax must be paid at the time the declaration is made. In order to guarantee the payment of the tax, the financial authority may seize any property of the taxpayer on the territory of the Protectorate. The Decree will remain in force until December 31, 1941. It is stated in the Press that the Decree is similar to the *Reichsfluchtsteuer* in Germany and that the proceeds will be used to subsidise the export of goods from the Protectorate.

CONSUMPTION OF SCRAP IRON AND STEEL IN THE UNITED STATES.—According to statistics issued by the American Institute of Scrap Iron and Steel, the consumption of iron and steel scrap in the foundries and steelworks of the United States totalled 35,006,000 tons in 1939, as compared with 21,518,000 tons in 1938, and 38,006,272 tons in 1937.

THE INSTITUTION OF MINING ENGINEERS.—As recorded in our columns at the time, Mr. Charles McDermid retired last summer from the position of secretary of the Institution of Mining Engineers, an appointment he had held since 1920. His son, Mr. John McDermid, who joined the staff of the Institution in 1925, and was made assistant secretary in 1932, was appointed to succeed him, and assumed full duties as secretary and editor at the end of July. It is pointed out in the Report of the Council, submitted at the annual general meeting of the Institution, held at Sheffield, on February 10, that since the beginning of September, Mr. John McDermid has been on military service as Major commanding a battery of the Royal Horse Artillery, and that Mr. Charles McDermid has returned to the Institution as honorary acting-secretary for the time being. Mr. A. G. C. Ratcliff, who was appointed assistant editor in 1932, has now been made joint editor.

THE "INVICTA" ROAD-LINE MARKING MACHINE.

MESSRS. AVELING-BARFORD, LIMITED, GRANTHAM.

FIG. 1. MACHINE MARKING ROAD LINES.

FIG. 2. MACHINE MARKING KERB.

FIG. 3. PAINT-DISTRIBUTING MECHANISM.

THE "INVICTA" TRAFFIC-LINE MARKER FOR ROADS.

THE motorist, in these days of restricted lighting after sunset, has reason to welcome the widespread adoption of the white dotted line down the centre of the roads he has to traverse, and both he and the more leisurely pedestrian must have realised the large amount of tedious labour that the painting by hand of these lines represents. The development of the road-line marking machine, illustrated in Figs. 1, 2 and 3, above, by Messrs. Aveling-Barford, Limited, Grantham, should enable existing lines to be repainted rapidly, since it is claimed that one man, when using it, can cover as much ground in the same time as five or six men painting by hand. Moreover, this rapidity of action is likely to result in more traffic lines being painted, as the cost of hand painting may have deterred some authorities from carrying out the scheme farther than absolutely necessary. The machine is not merely an adaptation of the old type of marker long used for tennis-courts, and so forth, but possesses some novel and interesting features. In the first place, the paint is applied to the road surface from a roller of resilient rubber, which is rotated by the friction with the surface over which it is traversed. This method of drive results in a definite brushing effect, so that the paint is applied to the surface in a manner which ensures proper adhesion while covering the strip completely.

The machine is pulled by a long handle, and is normally operated in the manner shown in Fig. 1. The two pneumatic-tyred wheels are carried on stub axles mounted on arms, which can be set so that one wheel is higher than the other, an arrangement enabling the machine to be used without tilting when kerbs are to be painted, as shown in Fig. 2. The white cylinder visible in both illustrations is the paint container, which holds a gallon of any recognised brand of line-marking spirit paint. From the container, the paint is led to a horizontal tubular distributor, the ends of which are sealed by corks to facilitate access for cleaning. This distributor can be readily made out in the enlarged view, Fig. 3, and from it a number of rubber tubes with quill-shaped ends spread the paint over the large sponge-rubber roller seen immediately below the tube ends. The smaller roller, which is in contact with the large one, ensures even spreading of the paint on the large roller. Just above the tube ends, a circular bar will be seen extending across all the tubes and there is another similar bar below the tubes. A link system causes the top bar to approach the bottom one when the paint supply is to be reduced or cut off altogether, thus squeezing the tubes. The indicating finger seen near the base of the handle in Fig. 3 limits the movement of the control bar, so that the flow of paint can be regulated to suit the particular type of road surface being painted.

The paint-flow control is adjusted by turning a disc at the top of the handle, but it should be understood that the flow of paint is stopped automatically as soon as the main roller is lifted clear of the ground. Conversely, when the roller is lowered to the ground, the paint commences to flow, both actions taking place through the action of the link mechanism on the control bar. The long arm seen to the left of Fig. 3 enables the machine to stand with the paint roller clear of the road surface. The short arm is for sighting the machine along, say, a chalk line and a similar arm is fitted at the rear for use when the machine has to be pushed instead of pulled. When making a dotted line, the traversing movement is not arrested, the handle being merely raised slightly to lift the roller clear of the ground while the gap is being crossed, no paint, of course, flowing during the passage of the gaps. The adjustable flow ensures the economical use of paint, as, obviously, a smooth road surface needs less paint than a rough one. The diameter of the paint roller is varied according to the surface, three rollers being provided to suit smooth roads, medium surface roads and rough roads, respectively. The rollers are readily removed. When painting is finished, the rollers are placed in containers attached to the handle, not shown in any of the illustrations, these containers having been given a few drops of methylated spirit which keeps the brushes soft until the depot is reached. The rollers, distributor and tube ends, etc., are cleaned with this spirit. The machine makes a line 4 in. in width. It has an overall width of 16½ in., and a height of 2 ft. 7 in. from the ground to the top of the handle.

THE SWISS ALUMINIUM INDUSTRY.—The exports of aluminium from Switzerland amounted to 7,500 tons in 1913, but by 1930 this figure had been doubled, and that for 1938 reached 30,100 tons.

EXPERIENCES WITH HIGH-TEMPERATURE HIGH-PRESSURE STATIONS.

(*Continued from page* 185.)

WE continue below our abstracts of the papers dealing with the operation of high-temperature, high-pressure power-station installations in the United States, which were presented at the annual meeting of the American Society of Mechanical Engineers at Philadelphia in December, 1939.

FISK STATION TOPPING-UNIT OPERATION.

By A. E. GRUNERT.

The Fisk station high-pressure topping plant has completed nearly two years of operation. The topping unit was the first capacity addition to the Chicago system following several depression years during which no new generating equipment was installed. It naturally followed that the basic trend at that time towards higher steam pressures and temperatures influenced design. The installation is not particularly different in design when compared with those contemporary to it, but, being an early topping installation, it is representative of development. The topping installation was first put into service on October 8, 1937, by a plant personnel having no previous experience with this type of equipment.

The installation consists of a 30,000-kW, 1,200-lb. per square inch, 900-deg. F. turbine generator, supplied with steam by two 375,000-lb. per hour boilers. All auxiliaries are electrically driven, except boiler feed pumps. Turbines for these three pumps take steam from the high-pressure header and exhaust to the low-pressure header in parallel with the topping turbine. The capacity of this topping installation was so chosen that the exhaust would supply the steam demand of two 25-cycle horizontal units. This combination forms, in effect, a flexible and efficient 90,000-kW cross-compound unit.

Turbine-Generator Operation.—The turbine-generator unit had an availability factor of 85·7 per cent. for the three months' operation in 1937, 90·7 per cent. for the year 1938, and 100 per cent. for the first six months of 1939. During the 22-month period from October, 1937, to July, 1939, there were nine outage periods only, three being attributable to the turbine itself. The two longest periods, from July 24 to August 23, 1938, and July 6, 1939, through the remainder of the month, were for general inspection and overhauling. During both of these periods repairs to spindle blading were necessary. The generator, since installation, has had a perfect availability record. An outage between October 8 and October 13, 1937, was necessary for the adjustment of a throttle-valve bushing and for minor adjustment and tune up of the governing gear. Further checks were made of the thrust bearing and shaft seals, and the dummy clearance was adjusted on October 23. The next outage, which started on October 27, 1937, is not attributed to the turbine, as it was caused by boiler carry-over deposits which caused the second inlet valve to stick. Heavy deposits of boiler carry-over were also found in the valves of the header system and these deposits were removed by flushing the header with water. The three subsequent outages of January 7, January 25, and May 20, 1938, are likewise not attributable to the turbine. The July 2, 1938, outage was necessary because the first and second admission valves were found to be sticking. Upon removal and inspection of the valves, the head of a ¾-in. cap screw was found lodged between the seat and disc of the second inlet valve. Upon inspection of the throttle valve it was found that this cap-screw head had broken from one of the screws which held the throttle-valve seat to the throttle-valve body. The sticking of the first inlet valve was caused by valve-stem packing which had lost its plastic qualities and had caused excessive friction. A combination die-formed resilient metal-ring and soft asbestos-ring packing was substituted, but this packing lasted only three weeks.

As the first general inspection of the turbine was scheduled to occur soon, the date of the inspection was advanced to July 24, 1938, because of the failure of this packing. It was found that the metal-foil packing rings had disintegrated under high temperature and particles had adhered to the valve stems. To ease the duty of the packing, the leak-off was changed from 225 lb. per square inch to approximately 4 lb. per square inch. Soft packing in die-formed rings was then installed and the number of rings was decreased to that required by the new pressure. This change proved satisfactory.

The inspection made at this time showed that the Stellite seat facings were in perfect condition. Three broken 3½-in. cylinder studs, which were judged to have failed due to defects in material or machining, were replaced in the bolting that is used for the turbine-

cylinder joint. The admission-valve operating mechanism needed correction where clearances did not correspond to the design dimensions. Lapped admission-valve-cover joints made up without gaskets held tight under high pressures and temperatures. Crane ring-type joints on all admission inlet bends were found to be in good condition. The trip-gear mechanism, which on several occasions had operated sluggishly, was fitted with an Alemite lubricating system during this outage. This change has materially improved its operation.

During the inspection, it was found that the lock washer which had been released from under the head of the broken cap screw, mentioned previously, had gone through the valves and nozzles and had lodged in one of the steam passages of the second moving row of impulse blading. The inlet edges of the first moving row of impulse blading were damaged by the passage of the lock washer, but the relatively slight damage done was corrected by local grinding.

The blade elements of the turbine consist of a 45-in. mean diameter two-row impulse wheel, followed by 34 rows of reaction blading. Nozzle blocks for the impulse blading are built up of a series of blade elements in which steam passages are completely machined before the elements are welded together as a single nozzle-block unit. The first row of moving blades is 2½ in. wide. All blades are made of a standard alloy known as "Cyclops No. 17-A," a 19-per cent. nickel, 8-per cent. chromium alloy. The integral shrouds of the first moving row of impulse blades were originally welded together in groups of five. During inspection it was found that many of the welded joints had cracked, although the welding between several pairs of blades still remained sound. The strength of the original welding, however, had been somewhat reduced during manufacture in securing a smooth cylindrical surface by turning down the blade tips after welding. The blades of the first impulse row were rewelded in pairs during overhauling and a much heavier welding bead was used than in the original assembly. The full section of the welding bead was left in place for strength in this repair.

A slight looseness was noted in the blades of the first moving row on the impulse wheel. The manufacturer did not feel that this looseness was harmful as the massive dimensions of the blades are such that tightness is assured by centrifugal force when the unit is up to speed. The shrouding of the second moving impulse row was found cracked in a number of places and a short piece of shrouding had broken off completely. One blade of this row was broken off where the shroud section failed and the tenon of the adjacent blade was injured. These two blades were replaced.

The shroud sections originally installed on the blades of the second moving row of the impulse wheel were of sufficient length to include six blades. These shroud sections were punched to receive blade tenons, the shrouding being applied by riveting of the tenons. It was concluded that cracking of the shrouding was caused by high stresses set up during riveting, and that harmful stresses would be avoided by carefully fitting new shroud sections so that they could be assembled in place without initial stress, the new shroud sections being held by welding around the projecting ends of the tenons. This shrouding was designed to group three blades instead of six, as in the original design, because of the temperature range through which this blading must operate. As a result of the failure of the original shrouding on the second moving row of impulse blading, it was decided that a replacement row of blades with integral shrouding should be designed and held in readiness for installation should further difficulty be experienced in this section of the turbine.

The reaction blading was found to be in good condition on this inspection. A slight looseness was noted in some of the assembled segments towards the centre of the spindle, but this looseness was not considered harmful as the blade segments become tight when up to speed. A few shrinkage cracks were found in the silver soldering of the reaction-blade shrouding towards the low-pressure end. These were resoldered.

Following this overhauling period in August, 1938, there were no further outages of or repairs to the turbine-generator unit during 1938 or the first six months of 1939. During March, April and May of 1939, however, the steam rate of the topping turbine showed gradual increase. This was particularly noticeable in the first part of May, when the steam rate of the turbine had increased to a corrected rate of 26·9 lb. per kilowatt-hour at 23,000 kW load. This was reflected in the division of load between the topping turbine and the low-pressure turbines to which steam was supplied. During the same period, a reduction of capacity had been experienced in the auxiliary turbines driving the boiler feed pumps. Fouling of nozzles and blading of these small turbines was suspected and successful washing restored their capacity.

The foregoing experiences led to the washing of the topping unit. The washing was to be accomplished with saturated steam supplied at a rate slightly above no-load full-speed requirements with the unit electrically tied to the system. Saturated steam at full pressure was to be obtained by reducing the steam temperature as far as possible with boiler regulation and then removing the remaining superheat by injecting de-superheating water into the steam header at a point as far removed as practical from the turbine. A suitable nozzle was installed in one of the boiler risers for this purpose and thermo-elements were inserted in existing wells at the turbine inlet and exhaust for accurate steam-temperature determination during the washing procedure. A steam-sampling outfit was set up which permitted checks to be made of conductivity of a continuous sample of condensed steam from the turbine exhaust.

With but one boiler in operation at reduced steam flow, steam-temperature reduction by means of boiler control was started at 11 p.m., on June 3. Adhering closely to a temperature reduction rate of 50 deg. F. per hour, a temperature of 650 deg. F. was reached at 3 a.m., on June 4. This steam temperature represented the lower limit obtainable by means of boiler control. At 3.15 a.m. water was gradually injected into the header and by 5 a.m. a steam temperature of 590 deg. F. was reached. At this point the conductivity of the exhaust-steam sample rose suddenly from 5·6 micromhos to 32,000 micromhos. As the washing progressed, the steam-sample conductivity decreased to a value of 1,000 micromhos after 3½ hours of washing. During this period several samples of condensed exhaust steam were taken for chemical analysis. Analysis showed the blade fouling to consist of approximately 40 per cent. soluble sodium silicate, 23 per cent. sodium hydroxide, and 23 per cent. sodium chloride. Other soluble inorganic salts made up the remainder of the deposit.

After the foregoing washing period, the temperature of the steam was gradually restored to normal and load was applied to the unit. At a load of 27,000 kW, the corrected steam rate of the topping turbine was found to be 24 lb. per kilowatt-hour. After a month of continuous operation subsequent to washing of the turbine, the topping plant was taken out of service for scheduled inspection on July 6, 1939. When the turbine was opened, 26 blades in the second impulse-spindle row were found broken. The only evidence of this failure noticeable while the unit was in operation was an increased steam rate which had not returned fully to normal after completion of the washing procedure. Blade failure, however, was not definitely expected as the unit ran in good balance before the inspection.

As mentioned when discussing the July, 1938, inspection, two blades and the shrouding of this second moving impulse row were replaced. The new blading, designed with heavier sections and integral shrouding made up for replacement following the 1938 inspection, was installed during the August, 1939, overhauling. The integral shrouding of these new blades was welded together so that groups of three blades were formed. The shrouding on the spindle reaction blading was originally of pure nickel. Failure of this shrouding, due to cracking, required its replacement with new shrouding made of stabilised 18 per cent. chrome, 8 per cent. nickel material. This shrouding was arc-welded in place with 25 per cent. chrome, 12 per cent. nickel weld rods.

Four 3½-in. diameter cylinder bolts were found broken on this inspection. As a result of this and of the bolt failures found in the previous inspection, all of the larger studs for the turbine joint were replaced. The new studs will be made of Triplex No. 3 bolt steel, a material which is now believed to be more suitable than that originally used for this high-temperature bolting service.

Although blading difficulties have been found in each of the two inspections of the turbine so far made, it is felt that the improvements accomplished will prove to be adequate, and that improved performance will result. Based on observed conditions and performance of the first impulse spindle row, the changes made should limit future blading maintenance to minor repairs.

Steam Generators.—The availability of the two steam-generating units of this topping installation has not equalled that of the turbine generator. The steam generators had an average availability factor of 61·2 per cent. for their operation in 1937, 80·2 per cent. for the year 1938, and 87·6 per cent. for the six months of 1939. Steam supply, however, has been available from one or both steam-generating units during all except two short periods in the first four months of operation of the installation. As the steam generators are similar in design, the major operating difficulties encountered with one were either indicated or experienced in the operation of the other. As a result, the improvements made in the boiler installations were made on each of the units in about the same sequence.

Steam was supplied to the high-pressure header system on September 18, 1937. After preliminary adjustments were made to the feed pumps and other auxiliaries, operation was continued, the steam produced being passed through the pressure-reducing and de-superheating equipment to the low-pressure header. In the early operation of the boilers, joint leaks developed where re-circulators entered the headers of the side-wall screens and also where economiser tubes entered the steam drums. Re-rolling of these joints failed to prevent the recurrence of leaks during further service, and it was necessary to seal-weld the joints for tightness. Inability to hold rolled economiser joints tight was attributed to strains due to variable economiser temperatures. Recurring leakage of rolled re-circulator joints was attributed to excessive joint strains set up by unequal expansion of the re-circulators and screen-wall tubes. Seal welding, where necessary, has prevented joint leakage but strains at the joints persist. These strains have, to the present time, caused no apparent difficulty other than the leakage before the joints were seal-welded.

During the initial operation of the installation, carry-over deposits were found to be accumulating in header valves and control valves of the turbine unit in quantities which were sufficient to interfere with valve operation. Tests for steam purity, made when the units were steaming at the rate of 230,000 lb. per hour, indicated that excessive carry-over was present when total solid concentrations in boiler water were maintained at 425 parts per million. Lowering of the water level resulted in carry-over of less than 1 part per million at this rating but, when ratings were increased to 310,000 lb. per hour, carry-over again became excessive. As 375,000 lb. of steam per hour is required from each boiler for designed operation of the topping installation, improvements for better steam purity were necessary. With a changed drum baffle and steam-scrubber arrangement, satisfactory steam purity has been attained at normal boiler ratings when the total solids in the boiler water were maintained, at 400 parts per million. Operation was continued with this steam-scrubber arrangement in 1938 and the first six months of 1939.

As ratings were increased, difficulties with furnace slag accumulations on the sloping portion of the secondary-furnace wall were experienced. The original design provided for operation of the secondary furnace as a dry-bottom furnace, the slag falling through the opening across the bottom of this furnace in a dry state and being removed by a hydro-jet system installed beneath the opening. This arrangement proved impractical, as slag built up on the sloping secondary-furnace rear wall in thicknesses of 4 in. to 12 in., and at times avalanched down in quantities and sizes so large that removal by the hydro-jet installation was impossible. During boiler outages in December, 1937, the secondary-furnace bottoms were changed, and all furnace slag is removed through the slag-drip holes of the primary furnace in liquid form.

Through this period difficulties were also experienced with failures of vertical slag-screen tubes and ruptures of tubes around the slag-drip openings in the primary furnace floor. The several changes necessary to correct these conditions required outages during January and February of 1938. The changes made consisted, first, of the addition of 12 re-circulating tubes between the upper slag-screen header and the lower distribution header to the screen; second, of offsetting alternate groups of two slag-screen tubes into the secondary furnace instead of into the primary furnace as originally designed; and third, of moving the burners 2 ft. 10 in. forward in the primary furnace. These changes had the effect of improving circulation and reducing the duty imposed on the tubes which previously had ruptured. A better balance in circulation between the screen-tube and floor-tube circuits also resulted. Further changes that were made to improve conditions in the floor-tube sections consisted of increasing the radius of tube bend in tubes around the slag-drip holes and the installation of water-cooling coils at these slag openings to retain a deeper protecting layer of molten slag over the floor tubes.

During the outage of the steam-generating units in April, 1938, lancing doors of improved design, with added insulation, improved hinges, and latching devices, were applied in place of the original doors. It was necessary also to apply additional insulation about the boiler setting to reduce the temperature at lancing galleries and in other localities about the boiler where operators must work. Repeated leaks from economiser-tube joints at the headers necessitated the completion of seal welding on all joints in the economiser sections at this time. During previous outages some seal welding of economiser-tube joints had been accomplished.

On May 20, 1938, an outage of the entire topping installation was necessary to remove pieces of straightening vanes which had come loose from their position in the topping-turbine exhaust line. These straightening vanes had been originally installed to direct the steam flow for more accurate metering through a topping-turbine exhaust orifice. As a result of the failure of this set of vanes, all straightening vanes in the header

installation were removed to prevent a recurrence of failure, and possible resulting injury to turbine blading.

During the outage of the topping turbine for inspection and overhauling, the boilers were alternately taken out of service for inspection, cleaning, and repairs. At this time, nine economiser-tube sections at the boiler drum, which had been seriously eroded by spray from a joint leak, were replaced in the economiser of No. 2 boiler.

Difficulties with blistering and rupturing of tubes in the vertical slag screen, and in the primary-furnace floor and upper generating-tube sections, had caused doubts of the adequacy of the boiler-water circulation and of the water treatment used in the installation. Apparently, some of the tube failures were aggravated by more or less loose deposits, which had accumulated at the points of tube rupture. These deposits had settled out of suspension in such quantities as to be evidence of sluggish circulation. Water lines in the interiors of the top-row tubes in the generating section were also evidence of inadequate circulation. In an effort to improve this latter condition, the top row of generating tubes was replaced with a changed design of tubes during outages of No. 1 boiler early in July, 1938, and of No. 2 boiler from August 27 to September 10, 1938. The original top tubes were parallel to the remainder of the tubes in the bank, while the new tubes were bent.

Soot-blower position changes were made during these boiler outages, for more effective cleaning of the heating surface. The soot-blower supply-header piping was also changed to secure higher pressure at the blower heads, resulting in higher jet velocities for more effective cleaning.

Operation of the boilers during the period from October, 1938, to February, 1939, was interrupted with several outages taken to clean tubes and make changes to improve circulation in the generating section. Restrictor plates in the uptake headers of this bank of tubes, altered design of top-row generating tubes mentioned previously, discontinuation of Akon treatment, and installation of tube cores in the upper ends of the top two rows of generating tubes were tried in efforts to prevent tube failures. These alterations failed to produce the desired result.

During the outage of No. 2 boiler between January 29 and February 6, and of No. 1 boiler between February 10 and February 17, 1939, distributor tubes made up of 1-in. tubing with a cone attached at the bottom were inserted in each of the uptake headers of the generating-tube section. The cone is arranged to divert the intense circulation of the bottom-row tubes through the 1-in. tube, while the 1-in. tube terminates near the top of the header and flow through it tends to induce circulation in the remaining tubes in the header. Sufficient equalisation of circulation has been attained with this arrangement to prevent further tube failures in the generating-tube section. With the changes mentioned, both boilers have operated for three-month periods and were taken out of service during May, 1939, only for inspection. No condition was found in these inspections which would have interfered with a longer service run on either boiler.

Due to difficulties experienced in other high-pressure boiler installations with cracking of drum metal at joint seats across which excessive variations in temperature occurred during operation, a changed design of economiser-tube joint at the drum and method of introducing feed water were recommended by the manufacturer. The changed position of economiser-tube entry to the steam drum resulted from a decision to change the drum baffling and steam-scrubber arrangement to the cyclone-separator arrangement developed by the manufacturer. These drum changes were accomplished during the August, 1939, outage of both boilers, while the topping turbine was inspected and overhauled. The installation of cyclone separators and changed scrubber arrangement is not expected materially to improve steam purity over that secured with the previous arrangement, but was adopted primarily to assure a maximum density in the water supply for boiler circulation.

During the August, 1939, outage, the boilers were thoroughly cleaned externally, and the tubes in the generating sections and screen and wall circuits were turbined. The turbining was not considered necessary to remove deposits, but was performed to make certain that the boilers would be in optimum condition for an extended service run.

In general, it appears that the tube failures experienced during these correction and development periods have been largely due, directly or indirectly, to sluggish circulation. While there are many factors in operation and design which may contribute to this condition, it would appear that the matter of solid-water downcomer supply is particularly important, as is also the matter of ample return circulating-tube area. It would also appear that where relatively high heat transfers occur, parallel circulation with unequal flow resistances should be avoided as far as practical design will permit. The several changes in these boiler units have been made largely with the object of improving one or other of these conditions. The records of improved availability indicate that efforts along these lines have been sufficiently successful to regard regular boiler-operating periods of six, or more, months' duration as a reasonable expectancy.

(To be continued).

ECONOMIC AND COMMERCIAL CONDITIONS IN MALAYA.

THE war has not only added to the normal difficulties of conducting international trade, but has made it more than ever imperative that British exporters should maintain and expand their trading operations overseas. In such circumstances, particular value attaches to the information collected by the various Trade Commissioners and presented in the reports issued by H.M. Stationery Office on behalf of the Department of Overseas Trade. Although there is, necessarily, a certain time lag between the collation of the relevant statistics and their publication as reports, the ruling conditions do not change, as a rule, so quickly as to invalidate the general conclusions. The report* on Malaya for the year 1938 covers the Straits Settlements, the Federated Malay States of Perak, Selangor, Negri Sembilan and Pahang, and the Unfederated States of Johore, Kedah, Perlis, Kelantau, Trengganu and Brunei.

The estimated population at the end of 1938 was about 5¼ millions, of whom about 42 per cent. were Malays, 42 per cent. were Chinese, and only about 0·5 per cent. were Europeans; the remainder consisted mainly of Indians. Generally speaking, the Malays are not a trading race. The import trade is mainly influenced by Chinese dealers, while most of the manual labour is done by immigrant Chinese and the Indians. English is the language used in commercial correspondence with firms in Malay and some of the dealers speak it. United Kingdom weights and measures are used, also the picul (133·3 lb.), and the kati (1·33 lb.). The chief industries are rubber growing and tin mining; the agricultural products are copra, areca nuts, pineapples, palm oil and coconut oil.

The year 1937 was a good one for Malaya. Not only were commodity prices, with a few exceptions, higher than those ruling in the previous year, but the rubber releases and the tin quotas were well above the corresponding figures for 1936. Exports were greater than in any year since 1929, while imports also exceeded those of any year since 1930. The balance of trade was in favour of Malaya to the extent of 24,000,000*l.* In 1938, however, commodity prices and the volume of exports were considerably lower and exports showed a decline of 37,500,000*l.* Imports also decreased, but in smaller proportion. The result for the year was still a favourable balance, but it was reduced to 2,500,000*l.* Although the value of the imports from the United Kingdom fell slightly in 1938 as compared with 1937, the position of this country improved, largely at the expense of Japan, whose goods were boycotted by Chinese dealers owing to the war in the Far East. Other factors adversely affecting prosperity in 1938 were labour disturbances, the possibility of another European conflict, and the general economic depression throughout the world. Large numbers of Chinese labourers lost employment through the reduction in the tin quotas; the smaller releases of rubber also affected employment.

During the year 1938 various ordinances came into force which were designed to raise and maintain the standard of quality of imported and exported articles or to protect the rights of proprietors of designs and trade marks. As in other countries, the railways had to meet increasing competition from road transport, both for passengers and goods. Some air-conditioned railway coaches that have been introduced have been appreciated, as well as improved travelling facilities and reduced fares. Improvements by the railway authorities at Port Swettenham are under consideration for providing additional harbour accommodation for ocean-going steamers. The number of motor vehicles in use in the country has grown considerably during the last few years and has created a demand for improved roads. The total entrances into and clearances from Malayan ports were slightly less in 1938 than in 1937, but those of British, Dutch and Norwegian nationalities were actually greater, in tonnage as well as in number, while the greatest diminution occurred in ships of Japanese nationality. Singapore is the principal port of call for ocean steamers.

Civil aviation has increased considerably during the past two years. In June, 1937, the Singapore Civil Airport was opened. It is equipped to accommodate both land and sea machines and is situated within three miles of the General Post Office and the business centre of the city. In addition, there are numerous well-equipped landing grounds and water alighting areas in various parts of Malaya, and there are four flying clubs. Singapore is now directly connected by air services with the United Kingdom, Australia, Amsterdam, Batavia, and Saigon.

Due to the manner in which imported goods are grouped, it is somewhat difficult to assess the share secured by the United Kingdom in competitive articles (those wholly or mainly manufactured), but it may be safely assumed that it amounted in 1937 to not less than 26·9 per cent., and in 1938 to not less than 29·7 per cent. The following list, from the classification of imported goods, indicates those articles which are of particular interest to engineering manufacturers: steel bars and sections, expanded metal, galvanised iron sheet, steel plates, railway materials, screws, steel girders, tin plates, tubes and fittings, wire cables, non-ferrous metals and manufactures thereof, cutlery and hardware, instruments, agricultural implements, engineers' tools, electrical goods, boilers, cranes, dredges, and internal-combustion engines. Hitherto, Germany has been the principal Continental supplier of internal-combustion engines, tin plates, iron and steel, and bicycle parts. Many of the articles listed above also afford opportunities for British manufacturers to secure business formerly placed with German firms.

* *Report on Economic and Commercial Conditions in Malaya, March*, 1939. No. 728. Department of Overseas Trade. London: H.M. Stationery Office. [Price 2*s.* net.]

SPLIT-PHASE FRACTIONAL HORSE-POWER MOTORS.

GENERALLY speaking, the essential difference between the three types of fractional horse-power single-phase motors which are now being so largely used for a variety of purposes lies in the relative values of their starting torques and currents. For instance, the split-phase machine has a starting torque, varying according to design and construction as well as output and speed, between 60 per cent. and 200 per cent. of the full-load torque with up to ten times the full-load current. Though this is quite satisfactory for some applications, for others the requirements are different. This has led to the development of the split-phase capacitor-start motor, in which the starting torque is usually between 1½ and 3 times the full-load torque with from 3 to 5 times the full-load current. As its name implies, this type of motor is fitted with a condenser, which is usually in circuit during the starting period, its object being to increase the starting torque. Some capacity can, however, be left in circuit during running to improve the power factor and give greater quietness, and when this is done the condenser is usually in two parts, an electrolytic portion, which is employed during starting only, and a small paper-insulated portion, which is continuously in circuit.

Where starting torques greater than those specified above are required, the repulsion start induction-type of motor can be used. This develops up to five times full-load torque with two to three times full-load current or, with some designs, three to three and a half times full-load torque with only about twice the full-load current. This improved performance is, however, offset by the facts that these machines are more complicated and expensive to manufacture and are not so reliable in service. Why this is may be made clear by saying that the only movable part on split-phase and split-phase capacitor motors is the simple centrifugal switch which open-circuits the starting winding when the machine has run up to full speed. This winding is nearly always designed on a 15-seconds rating only. Similarly, the electrolytic condensers on capacitor-start machines are usually rated for 40 to 60 one-second starts per hour. Repulsion-start induction motors, on the other hand, have a wound armature with commutator and brush gear and in the more usual types are also fitted with centrifugally-operated mechanisms which, in addition to lifting the brushes from the commutator, also short-circuit the latter internally, so as to convert the repulsion motor into an induction motor during the starting period.

Considerable interest, therefore, attaches to a further type of machine which has been designed by Messrs. Higgs Motors, Limited, Birmingham. This, it is claimed, combines the simplicity and reliability of the split-phase motor with the performance of the repulsion-start motor. This type of motor, which is known as the E.T.H. type, is made in outputs up to 2 h.p. at a speed of 2,800 r.p.m.; it is a split-phase motor with a new type of rotor which is provided with two windings. The one on the outer periphery is of the normal squirrel-cage type, while underneath are a series of single-turn coils, each of which completely encloses a portion of the core. This, it is claimed, gives good performance when used in conjunction with a condenser.

These new machines are made in two types: capacitor start for applications where the maximum torque

is not required, and capacitor start and run where maximum torque, combined with quiet running and low starting current, are essential. Both types have an approximate starting torque of 250 per cent. to 350 per cent. of full-load torque, but a high torque is maintained during the whole of the accelerating period and the pull-in torque, which is the minimum torque exerted by the motor at the time when the centrifugal switch comes into operation is considerable.

In the capacitor-start type, the pull-in torque is from 170 per cent. to 225 per cent. of the full-load torque, while in the capacitor start and run type it is 200 per cent. to 300 per cent.

SAFETY BELT-SHIFTING GEARS.

Although the individual motor drive for machines and machine tools has become common in recent years, there are still large numbers of such machines, even in quite modern shops, for which the belt drive from overhead line shafting is preferred. This method of drive, old as it is, seems still to be regarded as one which needs only casual attention, and it is not surprising, therefore, in view of the numerous accidents that have taken place in the past from such attention, to find that the Factories Act, 1937, lays down specific requirements with regard to belt-shifting gear. The very fact that the line-shaft belt drive is generally on a considerable scale, as regards numbers, makes the conversion of existing drives to fill the requirements a somewhat formidable matter in many cases. Messrs. Henry Lindsay, Limited, 47, Queen's-road, Bradford, have developed a unit for such conversions which operates on the safety dead-locking principle and thus complies with the regulations. The Lindsay unit, shown in Figs. 1 and 2, prevents the driving belt from creeping from one pulley to the other.

The gear dispenses with the old hanging lever and employs a pulley *a* rotated by pendant handles at the same level as the lever handle. The pulley is formed with a rim and a single arm in the centre of which is a slot *b*. The centre of the arm is pivoted on a bracket for attachment, the bracket also carrying guards for the chain or wire rope for the pendant handles. A block *c*, with a bolt in the slot of the arm, is attached to a rod *d*, which carries a second block *e*. This second block is attached either to the existing sliding bar which carries the shifting forks or to the lever operating the bar. The rod *d* is held in both blocks by set screws, so that adjustment in place is easily effected. It should not be shorter than, say, 1·5 times the diameter of the pulley, but, on the other hand, may be as long as is necessary. The slot is provided in the arm so that the stroke of the crankpin formed by the bolt of block *c* can be adjusted to suit the width of the belt concerned. The operation of the device can be readily made out from Fig. 1. In this view, the driving belt to the countershaft may be taken as being on the loose pulley, and with the normal arrangement of fork and lever there would be a danger of it working itself on to the fixed pulley to the right. With the Lindsay gear, however, the crankpin *c* is below the dead centre and the sliding bar is rigidly locked. The same locking occurs when the belt has been shifted on to the fixed pulley since the pulley *a* is rotated through more than 180 deg. in making the change. It will be clear that the arc of rotation is limited as the rod *d* comes into contact with the pivot of pulley *a* in either position of the pulley.

The operating pulley is shown as being carried on a bracket in Fig. 1, and in this view the block *e* is attached to the existing operating lever, the handle portion of which can be cut off if more convenient. The block may, however, be attached to the existing sliding bar, as shown in Fig. 2. Alternatively, the bracket may be dispensed with and the operating pulley may be attached to the lever, which is usually cut to suit. In this case, the block *e* is fixed to the bracket carrying the sliding bar. A three-point safety locking belt shift is available for existing two-speed or reverse drives involving two belts and two loose pulleys. For new installations the dead-locking belt shifter is made in a slightly different form. The pulley and pendant handles are the same as before, but the fork is made to slide on a fixed bar when actuated by the pulley and crankpin. The width between the fork legs, as well as the other parts of the gear, is adjustable. A spanner only is needed for the several adjustments. The fork can be inverted or bent to suit a vertical belt and in all types automatically recedes slightly at each end of the stroke, thus relieving the pressure on the edge of the belt.

The Late Mr. Freke Field: Erratum.—In our obituary notice of Mr. Freke Field, on page 179, *ante*, the date of his birth was incorrectly given as March 13, 1860, whereas the actual date was February 1, 1860.

SAFETY BELT-SHIFTING GEAR.

Messrs. Henry Lindsay, Limited, Bradford.

Fig. 1.

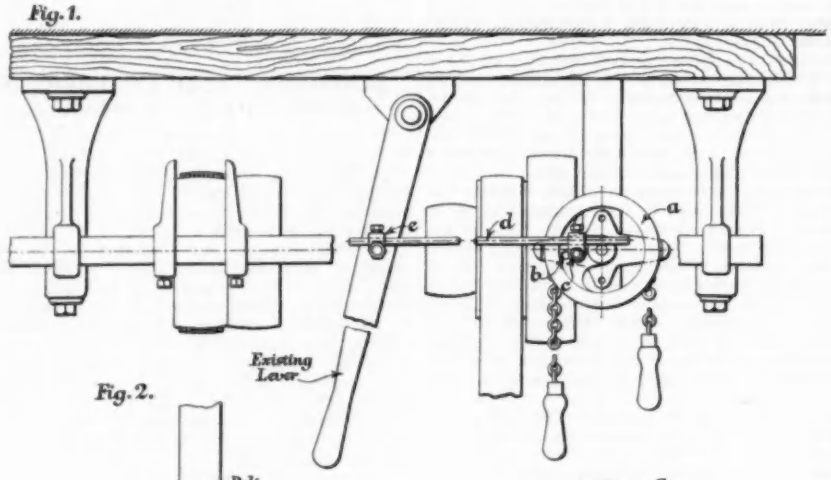
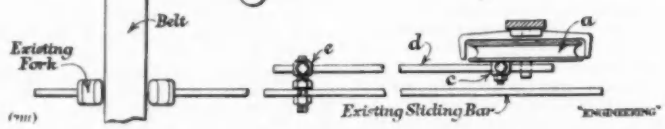


Fig. 2.



THERMOSTATIC BIMETALS.*

By S. G. Eskin and J. R. Fritze.

Many automatic regulating devices, in which temperature can be used for controlling the regulation, depend for their successful operation on thermostatic bimetals. In general, automatic control effects considerable savings in fuel cost and also safeguards the equipment on which it is used. Such equipment normally is left to operate unattended with full confidence that nothing is likely to happen to it. Since the use of thermostatic bimetals has so greatly increased in recent years and is so vital to such automatic regulation, considerable work has been done on its theory and application. .In this paper, the authors present a review of the available information on thermostatic bimetals which at present is scattered throughout numerous publications. A thermostatic bimetal is a metallurgical product made from two metals which have widely different coefficients of thermal expansion and which have been firmly bonded at their face of contact. When subjected to a change in temperature, the composite material will change shape, which change of shape is utilised for control purposes. In addition to having widely different coefficients of expansion, the components must have mechanical properties suitable to minimise hysteresis and provide adequate strength. For example, lead cannot be used as a component. The two component metals are usually of equal thickness and joined together in a firm bond by brazing or welding.

Thermostatic bimetals were known for many years as laboratory curiosities. Their first known application was in balance-wheel compensators, supposed to have been used as early as 1775; and as far back as 1858, Wilson obtained a U.S. patent covering a thermostatic bimetal. In 1863, in France, Villarceau published an analysis of thermostatic bimetals in the Annales de L'Observatoire Impérial de Paris. Wilson's patent covered a bimetal consisting of brass and steel, and, since the difference in the coefficients of expansion of the two metals was not very large, the movement of the bimetal was so limited that its practical value was small. With the discovery by C. E. Guillaume in 1898-1899 of the low-expanding alloy known as Invar, consisting of 36 per cent. nickel and the remainder iron, a new impetus was given to the work on bimetals.

At the present time, the manufacture of bimetals is still an art rather than a science, and the processes involved constitute closely guarded secrets. In one plant thermostatic bimetals were made by brazing two blocks of the component metals in a furnace in which a reducing atmosphere was maintained to prevent oxidation of the surfaces which were to be joined together. Sometimes blocks were used which were $\frac{1}{2}$ in. thick, 4 in. wide, and 12 in. long. Prior to brazing, one of the blocks was machined on both surfaces to a thickness of exactly $\frac{1}{4}$ in., while the other block was machined only on one surface. While the blocks were being brazed in the furnace, they were subjected to pressure by means of a hydraulic press to obtain a sound joint. It was very important to keep the metal surfaces clean before brazing. The blocks were usually kept in carbon paper, which prevented their oxidising. After the brazing operation, the exposed unfinished side of one of the blocks was machined to produce a total thickness of exactly 1 in., thereby ensuring that each component was of equal thickness before reduction by rolling. The blocks were then rolled down to the desired thickness, annealing being required at a number of stages. Special rolling mills were used for this work and those in the last stages needed to be extremely accurate to finish the product to within very close tolerances.

In general, the thickness variation of bimetals cannot exceed plus or minus 0·001 in. for thickness above 0·040 in. and plus or minus 2½ per cent. below this thickness. These close tolerances are necessary to obtain uniform performance, since the thickness enters into the deflection equation. It is interesting to note that, in most cases, the final thickness of each component is very close to half of the total thickness, even though in some bimetals the hardness of the separate components differs materially.

Properties of Invar and Related Alloys.—In making a study of the iron-nickel series, Guillaume discovered that some of these alloys possessed low coefficients of linear expansion at ordinary temperatures, the composition corresponding to the minimum coefficient being in the vicinity of 36 per cent. nickel. This alloy maintained its dimensions so nearly constant with ordinary variations in atmospheric temperature that he gave it the appropriate name Invar. Since Guillaume's work, the entire iron-nickel series has been so explored that the engineer can now use an alloy with any desired coefficient of linear expansion between zero and that of nickel. With such a range of low-expansion alloys available, the development of bimetals followed as a matter of course.

In an attempt to explain the expansion anomaly of Invar several theories were evolved. Some of the earlier views attributed the non-expansion to an inner molecular change. Another theory expressed the view that the non-expansion was caused by the high nickel content bringing the temperature of the A_3 transformation to the vicinity of room temperature, which made the transformation of γ into α progressive. However, it was shown that the position of the Ac_3 point for 36 per cent. nickel is about +400 deg. C., and that of the Ar_3 point about −100 deg. C., thus making impossible an equilibrium at ordinary temperature and indicating that the Invar would be in a decidedly unstable condition. Benedicks, in developing a theory for the expansion of Invar, reasoned that the alloy was in reality a two-phase system instead of being homogeneous. He proved his theory by a careful micro-study of the alloy which led him to four conclu-

* Paper presented at the Annual Meeting of the American Society of Mechanical Engineers, held at Philadelphia, U.S.A., from December 4 to 8, 1939. Abridged.

sions, namely :—(*a*) Strictly local, deep-etching spots occurred regularly throughout the metal; (*b*) these spots were often more concentrated at definite places, at which points considerably more iron goes into solution; (*c*) in an unetched surface, a darker, finely divided structure could be made visible in red light; (*d*) the deep-etching spots of Invar presented the same general characteristics as those observed in a larger proportion in a 30·5 per cent. nickel alloy where a two-phase microstructure was already known to occur.

From this evidence, Benedicks concluded that Invar possessed a duplex structure. As he was certain that Invar contained two phases, he reasoned that, since every transformation between two phases requires a definite time for its completion, by heating Invar quickly, sufficient time would not elapse for the transformation between the two phases to take place. In that event, the initial expansion would be a normal one and the coefficient would lie between that of iron (12×10^{-6}) and that of nickel (13×10^{-6}). However, when sufficient time is allowed, the change caused by the two-phase transformation will become noticeable. In other words, since Invar is a two-phase alloy, quick heating should show a thermal hysteresis, while if Invar were a one-phase alloy, no thermal hysteresis would be detected. Consequently, the high-expansion coefficient should be expected to occur at quick temperature changes if the alloy had two phases. To prove his theory, Benedicks conducted an experiment in which the thermal expansion of Invar was measured as a function of time. He developed special equipment whereby measurements of expansions were made with an apparatus which amplified the movement 14,000 times, time being measured simultaneously. As expected, the thermal hysteresis was very pronounced. For a given temperature change (50 deg. C.), a sample of Invar wire had an initial expansion coefficient of 13×10^{-6} or about the normal value for iron or nickel. The coefficient then diminished continually until, after 3 minutes heating, a considerable contraction had set in. Owing to this, the resulting length diminished so much after a lapse of about 11 minutes as to give an expansion coefficient of from $0{\cdot}2 \times 10^{-6}$ to $0{\cdot}6 \times 10^{-6}$. This is identical with the value established for Invar by previous workers, namely, $0{\cdot}4 \times 10^{-6}$.

In other words, Invar, upon heating, first expands to the same average degree as the separate constituents would expand for the same temperature change, and then, after a lapse of a few minutes, contracts to show a coefficient of expansion considerably less than that of the two elements. In applications of thermostatic bimetals where rapid rates of heating or cooling are encountered, this temperature-time hysteresis of Invar may affect the deflection of bimetals by an appreciable amount. The present methods of testing bimetals result in data giving the "static" (constant-temperature deflection) properties only. In order to detect this hysteresis effect, a "dynamic" (temperature-time deflection) test must be used.

Summary of Properties of Invar.—Invar is a nickel steel made either in the open-hearth, crucible, or electric furnace, containing about 36 per cent. nickel, 0·1 per cent. carbon, and 0·5 per cent. or less of manganese, with negligible quantities of sulphur, phosphorus, and other elements. It can be forged, rolled, turned, filed, and drawn into wire. It is very strong and ductile, and takes a high polish, giving an excellent surface on which extremely fine lines may be ruled. It is generally ferro-magnetic, but becomes para-magnetic in the vicinity of 165 deg. C. Some of the physical properties of Invar in the hot-rolled or forged conditions are given in the accompanying Table I.

TABLE I.—*Physical Properties of Invar.*

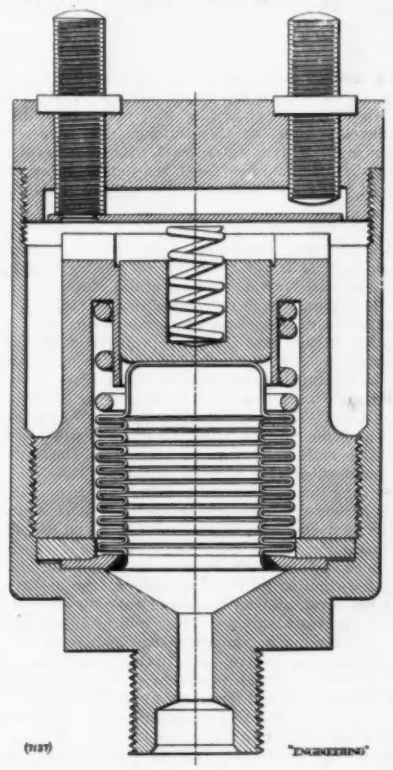
Melting point	1,425 deg. C. (2,600 deg. F.) (melts sharply).
Density	8 grammes per cc.
Tensile strength	29·0-37·9 tons per sq. in.
Yield point	17·8-26·8 tons per sq. in.
Elastic limit	9·0-13·4 tons per sq. in.
Elongation	30-45 per cent.
Reduction in area	55-70 per cent.
Scleroscope hardness No.	19
Brinell hardness No.	160
Modulus of elasticity in tension	21,400,000 lb. per sq. in.
Thermoelastic coefficient (thermal coefficient of Young's modulus).	500×10^{-6} per deg. C.
Electrical resistance	75-85 microhm-cm.
Thermal coefficient of electrical resistance.	$1{\cdot}2 \times 10^{-3}$ per deg. C.
Specific heat between 25-100 deg. C.	0·123 cal. per gramme per deg. C.
Thermal conductivity between 20-100 deg. C.	0·025 cal. per sec. per sq. cm. per cm. thickness per deg. C. temperature difference.
Linear coefficient of expansion (annealed).	$1{\cdot}7 \times 10^{-6}$ per deg. C.

The amounts of carbon, manganese, and chromium present appear to exercise considerable influence on the expansion. Above 200 deg. C., the expansion of Invar is nearly that of steel.

(*To be continued.*)

ELECTRICAL OIL-PRESSURE INDICATOR.

THE importance of indicating any failure in the lubricating-oil supply to an engine requires no emphasis, so that a new and improved type of electrical indicator for this and similar purposes, placed on the market by Messrs. Rotherham and Sons, Limited, Coventry, should be of interest. This appliance, which is known as the "R & S" electrical oil indicator, is illustrated in the accompanying figure. The indicator is essentially an electrical switch, arranged to break the circuit if the oil pressure fails, and thus to give audible or visual warning of the fault, say, by de-energising a solenoid, this operation, in turn, completing the bell or visual-



indicator circuit. Alternatively, in the case of an internal-combustion engine, the indicator can be arranged to short-circuit the ignition, also through a solenoid, and thus stop the engine.

The construction of the indicator will be clear from the illustration. It consists of a brass body into which is screwed a brass sleeve. The sleeve embraces the bellows, as shown, and also forms a guide for the plunger. The bellows are of metal, and are sealed by a leather washer clamped between the sleeve and the indicator body. The oil has access to the interior of the bellows through the hole in the bottom of the body, and when the pressure is normal, the bellows are expanded against the return spring shown surrounding the plunger. The latter, which is of vulcanite, is thus lifted. The small spring recessed in the plunger is then forced against the contact plate above it, closing the contacts and completing the solenoid circuit. The terminal plate is of moulded vulcanite, and the terminals are of brass. Should the oil pressure fail, the return spring compresses the bellows, and thus allows the contact plate to break circuit.

TELEGRAPHIC TYPE SETTING.

IN a paper which was read at the Institution of Electrical Engineers, on Thursday, February 8, Mr. H. H. Harrison gave an interesting account of the manner in which type can be set telegraphically and type-casting machines can be remote controlled for page printing, as distinct from teleprinter reception on narrow tape. The practicability of telegraphic type setting is the result of the invention and application of the integrating counting indicator to a key-board perforator. This enables the operator to judge the "castability" of a composed line of matter before closing the line. Casting machines of the Monotype class can be remote-controlled by one of several alternative methods. Machines of this class are already fitted with a keyboard perforator and integrating indicator and can be modified so that they can be controlled telegraphically with the same facility as the line casting machines of Intertype, Limited. No alteration to a line-casting type setter is necessary to enable it to be controlled telegraphically. Only a control unit, which operates the mechanism ordinarily controlled by the key lever, has to be attached. This controller is operated by the telegraph signals sent out over the line in seven-unit code.

A translating device is interposed between the receiving perforator and the line-casting type setter. This takes the tape and reads it letter by letter by means of a device designed by the Teletypesetter Corporation. Power-driven mechanism is thus set in motion and operates a group of permutation bars. An accepted method of positioning these bars is by means of perforated tape such as is used on Murray-Creed printers. At the present time, however, this tape is merely employed as a means of control, a mechanical relay being interposed between it and the permutation bars. Each setting of the permutation bars selects the desired key-bar of the type setter and the key-bars trip the matrices from the magazine one after the other and thus set up the line for casting.

Describing a typical production scheme for a newspaper office using line-casting machines, Mr. Harrison dealt with the methods of inserting extra items or withdrawing them from a received perforated tape. He claims that even where telegraphic control is not exercised it leads to an increase in operating efficiency, since a higher output is reached. While the most striking advantages of such apparatus are realised in the case of newspaper installations, it is also applicable where composing and casting machines are not installed in the same building. The control of line-casting machines by a perforated tape enables matrix selection to proceed at maximum line-casting speed. Pauses by the compositor are not so liable to be carried over to the machine and, as in telegraphy, indirect is superior to direct control since there is a reservoir of tape to draw on and speed irregularities on the keyboard are smoothed out. Touch operation by keyboard, with greater speed and accuracy, is a contributory cause of higher operating efficiency with indirect control. So much is this the case that even when there is no question of control over a line wire it has been found economical to operate a line-casting machine from a keyboard perforator adjacent to it.

A Teletypesetter will give 400,000 ems per week against 234,000 ems with manual operation. This increased output of nearly 60 per cent. allows ample provision for the capital cost of the additional equipment. Teletypesetter installations in the United States have shown an annual yield on the investment, after deducting operating expenses, of as much as 70 per cent. One of the advantages claimed for Teletypesetting is that the perforated tape is a convenient means of storing composed matter for reprints, as the type can be recast at a fraction of the cost and in much less time than that of manual resetting. To re-set the type it is only necessary to re-run the tape through the control unit; savings in storage space and on valuable metal are, therefore, possible. In conclusion, Mr. Harrison said that *The Scotsman*, working between London and Edinburgh, possesses the largest Teletypesetter installation in the world. The bulk of the copy is now cast by 9 p.m., using nine Teletypesetter equipped machines. With manual operation, this process was not finished until midnight. *The Glasgow Herald* has installed similar equipment for remote-control operation between London and Glasgow. Teletypesetting has made considerable headway in America and its prospects in Europe were beginning to look promising before the war.

CATALOGUES.

Pulley Blocks.—We have received from Messrs. Herbert Morris, Limited, Loughborough, a pamphlet describing their worm-gear pulley blocks to lift from 5 cwt. to 60 tons.

Lifting Magnets.—Messrs. Electromagnets, Limited, 48, High-street, Erdington, Birmingham, 23, have sent us a brochure describing their "Boxmag" magnets, with lifting capacities up to 20,000 lb.

Internal-Combustion Engines.—We have received from Messrs. John Fowler and Company (Leeds), Limited, Leeds, 10, a brochure illustrating a selection of typical Fowler-Sanders oil engines, supplied for various applications in this country and overseas.

Transformers.—A small pamphlet received from Messrs. Woden Transformer Company, Thornley-street, Wolverhampton, describes their non-industrial type of transformers. The firm also make transformers for low-voltage lighting, welding and similar purposes.

Temperature Controllers.—Messrs. George Kent, Limited, Luton, Bedfordshire, have sent us a folder describing the Multelec indicating temperature controller. This is an extension of their potentiometer range and is designed for use with heat-treatment plant where a temperature record may not be required. A list of current publications of the firm accompanied the folder.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

ABSTRACTS OF SPECIFICATIONS RECENTLY PUBLISHED UNDER THE ACTS OF 1907 TO 1939.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned, the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, etc., of the communicators are given in italics.

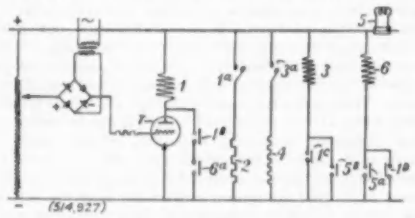
Copies of Specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery-lane, London, W.C.2, price 1s. each.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

ELECTRICAL APPARATUS.

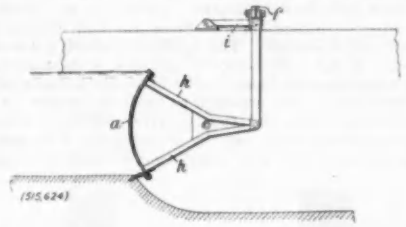
514,927. Supplying Regenerative Loads. The British Thomson-Houston Company, Limited, of London, and A. L. Whiteley, of Rugby. (1 *Fig.*) June 10, 1938.—The invention is for use on supply systems in which a substation is equipped with converters for the supply of traction loads which are capable of regeneration, and in which there is no parallel direct-current load. Hitherto, load resistances have been connected across the 'bus bars by electromagnetic relays which operate when regeneration takes place, but these are too slow in operation, and are known to permit voltage rises of several times normal. In the present arrangement, a thyratron T is normally negatively biased. To make the control more accurate, the bias voltage is derived by rectifying the alternating current which feeds the main rectifier. Under normal conditions, the grid voltage derived from the potential divider across the traction 'bus bars is insufficient to overcome the negative bias. Should regeneration occur and cause an over-voltage on the traction 'bus bars, however, the grid voltage is raised to a positive value, the thyratron becomes conducting and energises the coil 1 of



a contactor which closes the main contacts 1*a*. The loading resistance 2 is thus placed across the traction 'bus bars. The relay contacts 6*a* are normally closed, and when the auxiliary contacts 1*b* of the contactor close they short-circuit the thyratron and retain the contact 1*a* closed. The contactor's auxiliary contacts 1*d*, which are normally closed, now open. This de-energises the coil 6 of a flux-delay relay, which opens its contacts a short time after its coil is de-energised and releases the contactor 1, disconnecting the loading resistance 2 from the system. The relay 6 ensures that the resistance 2 is across the direct-current 'bus bars for the minimum time. If the period of regeneration is relatively prolonged, the time of opening of the contact 1*a* is determined by a directional current relay 5 in the main direct-current 'bus bars. This relay has contacts 5*a* which open when the regenerated current is zero to de-energise the relay coil 6 and after a delay the contactor coil 1 is de-energised, removing the resistance 2 from the system. When the contact 1*a* of the main contactor closes, auxiliary contacts 1*c* also close, energising the contactor coil 3, which places a high resistance 4 across the traction 'bus bars. The value of this resistance is such that, with no load on the 'bus bars, it loads the main rectifier beyond its transition point. When the contact 1*a* opens, the contacts 1*c* open, and thus the control of the contactor coil 3 is by the contacts 5*b*. These are controlled by the directional current relay 5, and open when the load on the traction system is above the transition value.—(*Accepted November* 21, 1939.)

HYDRAULIC MACHINERY.

515,624. Self-Adjusting Weir. Glenfield and Kennedy, Limited, of Kilmarnock, and W. M. Griffith, of Cambridge. (3 *Figs.*) June 7, 1938.—The weir is intended for use in maintaining the water in a reservoir at a predetermined level. The weir consists of a segmental shell *a* pivoted about its geometrical axis, so that the sill of the weir can be raised and lowered. The weir is self-adjusting and is controlled by two counterweights, each working in a well chamber beside the weir, which rise and fall with variations of the water level. The weir is carried by arms *h*, the other ends of which are connected by links with an overhead beam *f* from the ends of which the counterweights are suspended. Guide levers *i* are pivoted at one end to the beam and at the other end to the fixed pier at the respective side of the weir. The well chambers are interconnected by a culvert and have an intake on the upstream side at a predetermined level. Drainage pipes discharge downstream. In use, when the water in the reservoir rises above the predetermined level, the



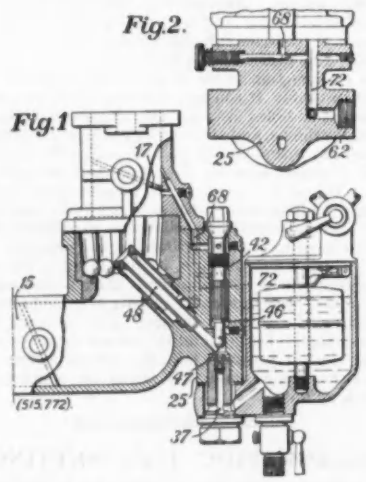
well chambers are flooded, the counterweights are submerged, and the weir falls to increase the outflow. When the water level is such that the intake into the well chambers is equal to the drainage, the weir remains stationary. If the water level in the reservoir falls below the predetermined level, the well chambers empty and the weir rises. (*Accepted December* 11, 1939.)

INTERNAL-COMBUSTION ENGINES.

515,772. Heavy-Oil Carburettor. A. W. D. Gladwell, of London. (4 *Figs.*) June 30, 1938.—The carburettor provides first for the emulsification of the heavy oil with high-temperature or "superheated" air, and, subsequently, its dilution with low-temperature air. It has been found that once the oil is properly emulsified and vaporised by the "superheated" air the temperature can be substantially reduced by dilution to the correct combustible mixture, without separation of the oil in liquid form. The carburettor main intake 15 leads to a vertical choke tube the internal surface of which is fluted and holds balls which vary the area of the choke. Above the choke tube is the throttle chamber. The screw plug connecting the float chamber to the boss 25 on the body of the carburettor has an axial bore 37, which is connected to the float chamber, and at the upper end of which is the main jet. The boss also houses the slow-running device consisting of a tube 42 in the lower end of which is a slow-running jet approximately at the normal float chamber level, and an extension tube 46 screwed over the jet and reaching down into a well 47 above the main jet. A spraying nozzle consisting of an inner tube 48, held by an outer tube in a hole in the boss, communicates with the well 47, and has a head the upper surface of which is grooved and forms the abutment against which the outer tube bears. Lower-temperature air is supplied to the main intake 15 from a preheater surrounding the exhaust pipe, while the "superheated" air is supplied

Fig.2.

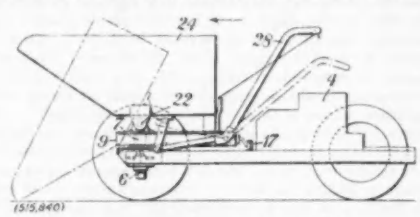
Fig.1



to an inlet 62 (Fig. 2) in the boss 25 from a coil exposed to the exhaust gases. The slow-running jet is mounted in the fuel channel between the well 47 and a duct 68 leading to the intake at each side of the throttle 17. The inlet 62 connects with a vertical passage 72 controlled by an adjustable needle valve (Fig. 2) and communicating with the well 47 by way of flutes around the extension tube 46. It is also connected to the outer nozzle tube. In operation, the engine is started up on petrol, and when hot enough, is changed over to paraffin. With the throttle still in the idling position, the paraffin flows through the main jet due to the static head, and fills the well 47 and the nozzle tube 48. It is also drawn up through the slow-running jet to meet the "superheated" air in the duct 68, where it becomes vaporised. On opening the throttle, paraffin is sucked up the nozzle tube 48 and "superheated" air is drawn through the grooves in the nozzle head, having an injector effect on the paraffin which becomes emulsified and vaporised by the "superheated" air. It then mixes with the main air supply, heated to approximately 45 deg. C., and the mixture is drawn into the engine at a temperature of approximately 60 deg. C. As the paraffin is drawn up the nozzle tube, the well 47 is gradually emptied; paraffin is then drawn directly from the main jet into the well, which now forms an emulsion chamber. (*Accepted December* 13, 1939.)

LIFTING AND HAULING APPLIANCES.

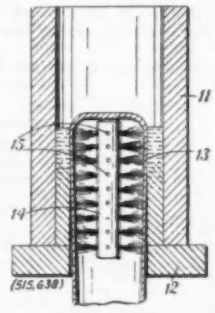
515,840. Tip Wagon. William Jones, Limited, of London, and T. McC. Ferguson, of London. (4 *Figs.*) June 10, 1938.—The invention is a contractor's tip wagon, which is compact and easy to manœuvre. The wagon has two pairs of running wheels, one directly driven by a motor 4. The other pair of wheels is spring-mounted upon a cranked axle 6 at the centre of which is a pivot pin 7 passing through a bearing boss between the frame members and anchored to a subframe 9. The subframe carries skid plates attached to the underside



of its main transverse member. A skid track is supported on the main frame, the arrangement minimising rocking of the subframe about its pivot 7 in the direction transverse to the main frame. To provide longitudinal stability, a channel-section track 17 is secured to the main frame and is engaged by a roller carried upon a transverse member of the subframe. The subframe has trunnion plates which carry a pivot spindle 22 for the body 24. In the untipped position it rests upon a block and is held by a hook. A U-shaped handle, which consists of a pair of levers 28 joined by a transverse hand-grip, is pivoted on the subframe and connected by a toggle link to the wagon body. The driver stands on a footplate and steers the wagon by moving the hand-grip in a horizontal plane, since this swings the subframe and axle about the pivot 7. To empty the body the hand-grip is depressed to release the hook and tip the body to the position shown in chain-dotted lines. (*Accepted December* 15, 1939.)

MINING, METALLURGY, ETC.

515,638. Ingot Mould for Hollow Forgings. E. F. Jones, of London. (2 *Figs.*) June 8, 1938.—The invention is a mould for casting ingots for use in the manufacture of large hollow steel forgings in excess of, say, 12 in. in diameter. The mould consists of an upright outer portion 11 standing on a base 12. The base has



a central aperture through which a core 13 is introduced from below. The core is hollow and fits the aperture in the base. Metal is poured into the mould from a tundish which ensures that the molten metal is poured at a constant rate and is kept at a constant temperature. Inside the core is an air pipe 14 having jets 15, so that air can be played upon the core during the casting operation. The process commences with the core just projecting through the base. Simultaneously with the commencement of the pouring the core is slowly lifted, keeping pace with the rate of pouring. The core is tapered, with its largest diameter at the top, so that the upper portion of the core is in contact with the molten metal and preserves the internal diameter of the casting, and the lower portion, which is adjacent the solidified and contracting metal, is of sufficiently smaller diameter to be out of contact with it so that friction is avoided. At the conclusion of pouring the core 13 is withdrawn upwards. Hollows thus produced have a smooth internal surface of good crystalline structure owing to the rapid solidification of the metal. Being of comparatively thin wall thickness, piping and segregation are lessened. (*Accepted December* 11, 1939.)